M.
e | 11

63294/B

Vol. 2

Richd Stocker

The Library of the
Wellcome Institute for
the History of Medicine

MEDICAL SOCIETY
OF LONDON

Accession Number

Press Mark

SWEDENBORG, E.
Vol. 2

THE PRINCIPIA.

LONDON:
PRINTED BY WALTON AND MITCHELL,
Wardour-street. Oxford-street.

H. s. 9

MEDICAL SOCIETY OF LONDON

THE

PRINCIPIA;

OR,

THE FIRST PRINCIPLES OF NATURAL THINGS,

BEING

NEW ATTEMPTS

TOWARD A

PHILOSOPHICAL EXPLANATION OF THE ELEMENTARY WORLD.

BY

EMANUEL SWEDENBORG,

LATE MEMBER OF THE HOUSE OF NOBLES IN THE ROYAL DIET OF SWEDEN,
ASSESSOR OF THE ROYAL METALLIC COLLEGE OF SWEDEN,
FELLOW OF THE ROYAL ACADEMY OF SCIENCES OF UPSALA, AND OF THE ROYAL ACADEMY OF SCIENCES OF STOCKHOLM,
CORRESPONDING MEMBER OF THE IMPERIAL ACADEMY OF SCIENCES OF ST. PETERSBURG.

TRANSLATED FROM THE LATIN

BY

THE REV. AUGUSTUS CLISSOLD, M.A.

VOLUME II.

LONDON:

W. NEWBERY, 6, KING STREET, HOLBORN;
H. BAILLIÈRE, 219, REGENT STREET;
OTIS CLAPP, SCHOOL STREET, BOSTON, UNITED STATES.

1846.

48

CONTENTS OF VOLUME II.

PART II.

PAGE

Chap. XI. On the Conjunctive Force of the Magnet, as exercised upon several pieces of iron 1

XII. On the operation of Iron and of the Magnet upon the Mariner's Needle; and on the Reciprocal Operation of one Needle upon another 64

XIII. On other Methods of making Iron Magnetical 72

Appendix 93

XIV. The Declinations of the Magnet, calculated upon the foregoing principles 95

XV. On the Causes of the Magnetic Declination 144

XVI. Calculation of the Declination of the Magnet for the year 1722, at London 156

PART III.

Chap. I. Comparison of the Sidereal Heaven with the Magnetic Sphere .. 229

II. On the Diversities of Worlds 240

III. The philosophical argument resumed concerning the Fourth Finite, and its origin from the Second Elementary Particle 249

IV. Of the Universal Solar and Planetary Chaos, and its separation into Planets and Satellites 251

V. On the Ether or Third Element of the World 273

VI. On the Fifth Finite 301

VII. On the Air or Fourth Element of our System 303

VIII. On Fire, or the Actives of the Fourth, Fifth, and following Finites 311

IX. On Water, or the purely Material Finite 330

X. On Aqueous Vapour or the Fifth Element of the World 336

XI. On the Vortex surrounding the Earth, and the Earth's Progression from the Sun to the Circle of its Orbit 344

XII. On the Paradise formed upon our Earth, and on the First Man .. 355

Appendix 363

Preface to the Treatise on Iron, in Swedenborg's Mineral Kingdom 369

Ditto on Copper, in ditto 375

Index of Subjects 385

Appendix 407

THE PRINCIPIA.

PART II.—*continued.*

DIRECTIONS TO THE BINDER.

In re-binding this Work, be careful to cancel the first sheet and half in Vol. I., consisting of Title, Contents, Preface, &c., and supply their place with those at the end of this volume; to be followed by the " Introduction by the Translator."

THE PRINCIPIA.

CHAPTER XI.

ON THE CONJUNCTIVE FORCE OF THE MAGNET, AS EXERCISED UPON SEVERAL PIECES OF IRON.

A PRIORI OR FROM FIRST PRINCIPLES.

One magnet may consociate with itself in order several pieces of iron, and may inclose all within one and the same sphere. For if from two spheres, *i.e.* of the magnet and of the iron, there arises a larger which incloses the magnet and the iron, and which penetrates the iron, conjoins and allures it to itself, then it follows, that from several spheres may be formed one larger, and thus that innumerable pieces of iron may be mutually joined together, and made to follow the same magnet, as if tied and bound to it.

2. *The conjunctive or attractive force of the magnet, may by the application of iron, or by armature, increase, and be rendered stronger.* From two or more spheres exists one that is larger. Consequently by the application of iron, the magnetic force receives an increase. Moreover, a magnetic body is not so cohering and contiguous as an iron one. For when iron is moved toward a naked magnet, then, by reason of the looser and lighter contexture and coherence of its parts, it cannot become affixed and attached. Hence there is a double cause for the accession of force to the magnet by means of an armature.

3. *There can be no two magnets absolutely similar to each other as to their conjunctive force;* as we have before intimated.

For some there are which have a spacious and perfectly regular sphere; some, a spacious but not a regular sphere; some, a spacious sphere, and but slightly ligatory; some are generous and noble, some worthless and ignoble; some energetic and quick, some tardy and sluggish; some exceedingly pregnant and enriched with forces, some poor and sparing in their communication of forces. Some, like iron, operate at a considerable distance; some will not operate at a distance, but exercise a powerful influence upon adjacent objects. These differences owe their cause and origin to the quantity of the iron parts, and the regularity of their situation. Not therefore to travel over again the same ground, we shall content ourselves with this simple recital of the differences.

A POSTERIORI OR FROM EXPERIMENTS.

EXPERIMENT XLV.

Fig. 46.*

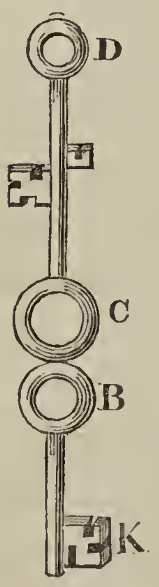
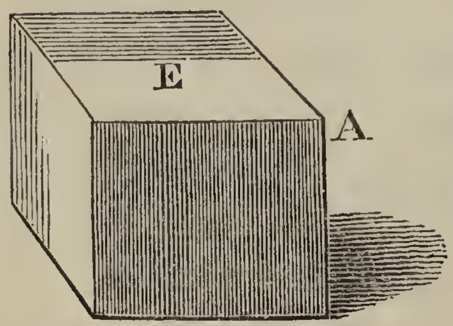


Fig. 46. Over the generous and large magnet A, let there be held, at a considerable distance, two iron keys B and C, never before endued with any magnetic force. From the key C let BK be suspended; these two are sometimes supported by a third key D. If D be elevated to a greater distance from the magnet, together with the adhering keys C, B, then they will separate from each other and fall down. The keys however may be moved to a great distance from the magnet before they are loosened from each other; for it is observed by Derham, in the *Philosophical Transactions*, n. 303, that the magnet of the British Royal Society had suspended two keys at the distance of 8, 9, or 10 feet from itself.



In this experiment we observe, that the attractive force of the magnet passes through the iron itself, and thus becomes extended to a considerable distance. Still it is surprizing that the key BK is not attracted by the magnet A so strongly as by the key C; for it will adhere to the latter, but not to the magnet. Yet the magnet is the cause of the attraction; for the keys become loosened one from the other immediately they are raised higher above the magnet. Why then does the key C, which is so remote from the magnet, attract the key B more strongly than the magnet A does? Some perhaps may think that the key B is not attracted by the magnet, but is repelled against C; but this is untrue; for B is most strongly attracted by the magnet, as will be evident from the following circumstance. If the pole of the magnet be at E, and if the key B be carried round it in a circular direction, but at a considerable distance, namely, in the periphery of a large circle, the inferior part K will be drawn toward E, and the whole key will acquire a very oblique position, and appear in its motion to describe a conical surface. In instituting this experiment, moreover, it is observable, that if the axis of the magnet be perpendicular to the horizon, the keys may, without losing their attraction, be elevated above the magnet higher than they may be when the axis is parallel to the horizon; and if the north pole of the magnet be turned upwards, then may the keys be raised to the highest distance from the stone of which they are capable, without destroying their mutual coherence.

---

* In the original, plate IX., fig. 4.

EXPERIMENT XLVI.

Fig. 47.*

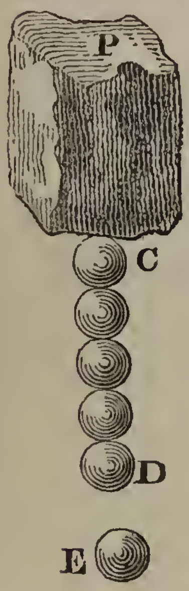
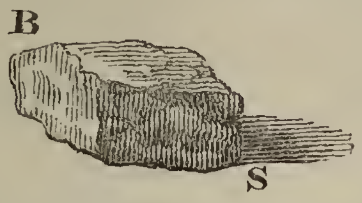


Fig. 47. If a number of small iron globes C, D, E, applied one to the other and suspended from each other, be attracted in a rectilinear series perpendicular to the horizon, by the pole C of the magnet PC; and if the cognominal pole B of another magnet BS, be slowly brought toward the inferior globe E, from which it has been removed to a considerable distance, it will separate the globe E from D, and will repel the entire series of globes DC, by giving it an oblique position.

We always observe that the cognominal poles of two magnets mutually repel each other. This being granted, the pole C of the magnet CP attracts to itself the series of globes E, D, C, in a direction from E to C; and thus all the lowermost parts of the globes will be the cognominal poles of C, and the uppermost parts will be the cognominal poles of P.



---

* In the original, plate IX., fig. 5.

If therefore the pole B of the magnet BS be the cognominal of C, that is to say, of the lowermost parts of the globes, then all these must be repelled by the pole B. If the repelling force of B be greater than the attracting force of the pole C exercised upon the remotest globe E, upon which it can operate only but little; then the globe E, repelled too much by the pole B, will become separated from the others. Instead of the iron globes, the same experiment may be very readily made with needles, which, suspended by their extremities and adhering one to another, will constitute a series. If the magnet BS be moved round the lowest, it will repel it, and bring it into a circular movement, as Wolffe has beautifully remarked in his *Meditat. Ingen.*, vol. iii. But if the pole S of the magnet BS be presented to the lowermost needle, the latter will immediately fly to it.

EXPERIMENT XLVII.

If to the pole of the more powerful magnet be applied an oblong piece of iron, lying in a smooth horizontal plane, and if a pole of another name, but of a weaker magnet, be applied to the other extremity of the iron; then, if the latter magnet be drawn slowly backward, so that the iron remain in the plane, the iron will often adhere to it; being forced away from the stronger magnet.

There are many who have observed this phenomenon; as for instance, Kircher in his book on the magnet; Gassendi, *ad Diog. Laert., p.* 205; Rohault, in his *Physics*, part 3., chap. 8., § 54; De la Hire, in *l'Hist. de l'Acad. Roy.*, A.D. 1717.

EXPERIMENT XLVIII.

If a magnetic needle be placed in the equator of a spherical magnet parallel to the axis of the magnet, and if an iron ruler be applied to the extremity of the needle; this ruler will adhere to the needle so firmly, that it will be enabled to draw it round the whole of the magnet, and to bring it into any position.

EXPERIMENT XLIX.

Fig. 48.*

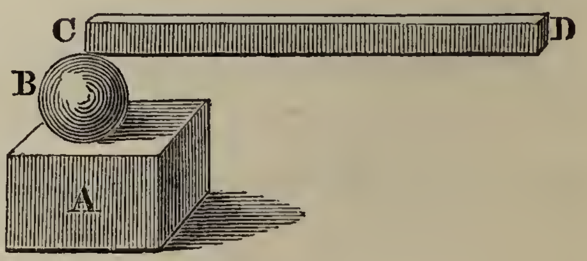


Fig. 48. If to a magnet A of excellent power, adhere an iron spherule B by attraction; and if an iron ruler CD touch that point of the spherule which is opposite to the point of contact with the mag-

net, the ruler CD will be able to withdraw the spherule from the magnet; but if the magnet be of weaker power, then will the ruler not be able to do so. De la Hire, who made this experiment with two iron rulers, the smallest of which was that which adhered to the magnet, observes, that the large ruler abstracted indeed from the magnet the smaller; but still that both became separated from each other, after being withdrawn from the magnet two or three inches.

---

* In the original, plate XI., fig. 1.

EXPERIMENT L.

The point of a steel needle was blunted, but so that the head still remained the thickest part. The point was then applied to a most powerful magnet, and the head to an iron rod. When the rod was drawn away from the stone, the needle always firmly adhered to it and abandoned the magnet. The head of the needle being then applied to the magnet, as also the point to the iron rod, the needle was sometimes drawn away from the magnet, and sometimes not, when the ruler receded as before.

The point of the needle was then made very sharp; and the head was highly polished: in this case, when the point was applied to the magnet and the head to the iron ruler, the needle always adhered to the latter, and might thus be drawn away from the magnet. But when the head of the needle was applied to the magnet and the point to the ruler, the needle did not adhere to the ruler, but remained affixed to the magnet. At first appearance therefore I thought, with other philosophers, that the needle adhered to that body which it touched in the greater number of points. This opinion however I have found from many experiments to be erroneous; for a key whose degree of polish was considerable, was placed on the plane pole of the magnet, so as to be in contact with it throughout a considerable portion of surface; and the round head of another key was applied to the round head of the former key; so that the contact of the two might be only in one point; nevertheless the second key drew the first away from the magnet. This experiment I made together with Hartsoeker, who affirms that in every case he observed the same paradox; as is noticed also by De la Hire, in *l'Hist. de l'Acad. Roy.*, A. D. 1717, who supposed that iron acted as a stronger magnet in attracting iron than the magnet itself; and that hence it was that one iron ruler took away from the magnet the other; this however appears to be too hazardous an assumption; since iron that is endowed with scarcely any magnetic force withdraws another piece of iron from a most excellent magnet. Moreover the difficulty is not solved as to the manner in which a weaker magnet abstracts the iron from a stronger, as in experiment 47. One philosopher indeed supposes that the weaker magnet acquires a degree of strength from the stronger; but it has still to be demonstrated, that the weaker becomes stronger than a most excellent magnet; which, whether it can be conceded or conceived, I very much doubt. Manifold indeed are the phenomena of magnets; yet how few of them can be understood by an intelligent mind, is evident from experiments 47 to 50; experiments which may be classed among those which of all others are the least comprehended.

EXPERIMENT LI.

If a number of common needles, or small iron plates, be ranged together in a series close to one another; then, when the magnet touches one needle or plate, they will all cohere with each other and with the magnet; but the second will cohere with the first more strongly than the third with the second, the coherence lessening in proportion as the needles or rods are the more distant from the magnet. The force of the magnet therefore passes from one piece of iron into the other; or, if the magnetic force be excited in one piece of iron, so also it is in the next, and thus onwards to the last. Effects analogous to these may be seen in two iron whirling wheels, one of which touches the magnet and the other is suspended from the former; so that the two are in contact at one point, cohering, in virtue of the attractive force of the magnet; in which case each wheel may be swiftly gyrated in a direction opposite to that of the other, and yet the gyration will be found not to interfere with the attraction.

EXPERIMENT LII.

If a plate of iron be rubbed lengthwise along a magnet; the part which last touched the magnet has more strength than the part which was first applied; so that, in order for the weaker extremity of the iron to receive the same forces as the other, it must be rubbed upon the opposite pole of the magnet.

EXPERIMENT LIII.

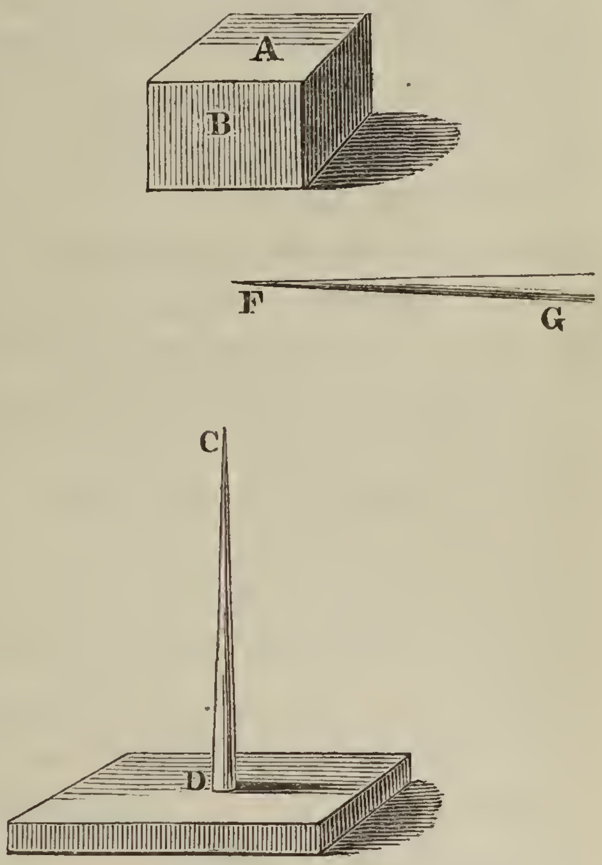
If a well tempered steel ruler be cut into several rectangular parts; if these again be placed upon a copper plate, in an order different from the one in which they before cohered; and if they be well pressed together, so as to form as it were a united body; if in the next place a magnet be pressed closely down upon them, then will the ruler become impregnated with forces greater in proportion as the parts the more closely touch each other; but if these scarcely touch each other then will there be communicated only a slight degree of force.

EXPERIMENT LIV.

Fig. 49. Let the needle CD stand perpendicularly on the table D, attracted by AB, the magnet placed over it; let the needle FG be then moved across, so as to pass between the needle CD and the magnet AB; in this case, the needle CD will immediately fall, the attraction no longer continuing.

We see then how much the magnetic force may be deflected from its track, and how easily, by the operation of a very slight cause. For the needle FG takes away all the force which before was determined to CD, and inflects it to FG. Now any person acquainted with the motion of water and of fluids may easily see, that this phenomenon repudiates all the laws of running fluids: consequently, that the magnet does not operate by effluvia, or by any other kind of fluid.

Fig 49.*



EXPERIMENT LV.

An iron plate, which was drawn over a most excellent magnet, became impregnated with considerable force. It was then placed on an anvil, and hammered for some time. At length it lost all the forces it had before received from the magnet; for it could carry only the lightest particles of grit or ore, in consequence of the violence communicated by hammering, and such indeed as all iron experiences from the same cause; it was unable, however, to lift even the lightest needle.

---

* In the original, plate XI., fig. 2.

Grimaldi, in the course of his physical observations, makes mention of a like result from the same experiment. But what is it that thus expels the forces from the iron? The parts of the iron by hammering become separated from each other, the pores are changed, a contact between other parts is effected; and though in the iron no other change is experienced, yet this alone is sufficient to disturb and dissipate the magnetic forces so that none shall remain. Is then the figure of the pores the cause of the attraction or of the magnetic virtue? Assuredly not; for what is a pore but an empty space naturally inert? But when the situation of the parts is changed, is there not a force expelled? and since the hammer acts upon this force, must it not be a corporeal substance? That one body may act upon another is intelligible enough; but how it can act upon substances altogether diverse, is incomprehensible. Yet we see the body act upon the mind, which is a something perfectly distinct from the body! May it not be in like manner, that the blows of the hammer act upon the magnetic force, even although the latter might not be a corporeal substance, but one of a different nature; yet having a relation to the former the same as that between the mind and body? But inasmuch as we observe iron filings, endued with magnetic forces, immediately lose them when the parts become confused with each other; are we to conclude that in like manner hammered iron loses its forces, because the different parts become commingled one with the other and are located in a different order? This indeed appears to be highly probable. Still the difficulty remains as to the manner in which the forces are destroyed by the disturbance of the arrangement of the parts.

EXPERIMENT LVI.

If a plate of iron, which has been rubbed against a very powerful magnet, be impregnated with considerable magnetic forces; and if it be submitted to the fire so as to become red hot, and in this state be applied to iron filings, it will not attract a single particle,—a manifest proof that there does not remain in the heated plate any attractive forces. This agrees with experiment 29, relative to the magnet submitted to the fire; and which lost the power of attracting iron filings. Thus the iron does not differ from the magnet; nor is the magnetic force in the iron diverse from that in the magnet; if therefore the fire eject the force from the one why does it not from the other? Here then we see how surprizing are the properties of the magnetic force! At one time the fire acting upon it, at another not acting; for the force passes unimpaired through the flame of spirit and oil, yet is expelled and destroyed by fire in the case of iron and stony bodies.

EXPERIMENT LVII.

Since an iron plate is divested of its magnetic forces in the fire, it remains to be ascertained whether the magnet would communicate its force to ignited iron; and whether when thus communicated it would remain in the iron. At first sight it might be thought that this experiment was superfluous; for if in experiment 56 the fire ejected the magnetic force out of the iron, it would also now expel from it any force it had received; for the fire which exists in highly ignited iron does not differ from any other fire; and yet how contrary are the real phenomena to such a course of reasoning! A circumstance which ought to teach experimentalists how slowly, how cautiously they should proceed in physics; and how little we ought to confide in experiments, unless frequently repeated by the most dexterous manipulators. Indeed in this science, the adage inculcated by chemists will be found to apply, *Omnem festinationem esse a diabolo;* for haste combined with abstract argument derived from one or two observations, cannot but lead constantly into error. In the year 1725, a plate highly ignited was drawn over the pole of an excellent magnet, and plunged into filings of iron; yet it manifested no symptom of attractive force. The friction upon the magnet was repeated, but no force was communicated to the iron; after the plate had cooled, it possessed no greater power of attracting than any other plate. In the year 1727 I repeated the same experiment before numerous spectators, with another excellent but armed magnet. The same iron plate was strongly ignited: it was then drawn along over the foot or pole of an armed magnet, and then plunged into filings, when it exhibited a strong attractive power; the filings adhering on all sides like a beard; nay, even when cold, the iron retained the same degree of strength. Wondering at a result so unexpected and so contrary to the former, I repeated the experiment on the following day with a piece of iron wire. I took also a fresh quantity of filings, and carefully attending to every particular lest I should fall into any mistake, I arrived nevertheless at the same result; for the iron wire, when ignited, was still impregnated with the magnetic force, and retained it even after being allowed to cool. Now what conclusion can we draw from results so opposite? Is it that some magnets are enabled to communicate their force to ignited iron, and others not? or is it that at one season of the year a phenomenon may be produced which at another cannot? Has the armature anything to do with it? Does it in any measure depend upon a given degree of ignition? does it depend upon the iron? It were however better to reason cautiously from experiments of such a nature.

EXPERIMENT LVIII.

A magnet was placed on a rotatory table. On another table was placed a mariner's needle, distant from the magnet 10 feet; so that the axes of the stone and of the needle were in the same horizontal plane. The needle was brought into a state of rest; then the table with the magnet was turned round, and a motion of the needle was observable; but before it began to move an interval took place of somewhat less than two minutes. The magnet was then moved nearer to the needle; the table on which it was placed being now at 7 feet distance; and, when again revolved, the needle also was moved; but between the beginning of the motion of the magnet and that of the needle the interval was shorter than before. The magnet was again moved nearer towards the needle, there being between the two an interval now of only 3 feet. As soon as the magnet was turned round, the needle was moved; nor was any delay in the motion of the latter any longer observable. The interval between the motion of the magnet and that of the needle was too short to enable me to take any accurate observation of it; but I used my endeavours to detect the proportion between the times in which the motions of the needle took place, and the reciprocal distances of the two bodies from each other, in order to ascertain the velocity of the magnetic forces. Hitherto however the extreme velocity of the motion has prevented me from coming to any accurate conclusion upon the subject. Still the attempt, such as it was, appeared to me to be too worthy of notice to allow it to be passed over in silence.

EXPERIMENT LIX.

If a needle and a magnet be situated at such a distance that the one acts upon the other, the needle is attracted by the pole of the magnet; that point of the needle which is not the cognominal being directed toward the pole. If now a second magnet be placed near the first, in the same horizontal plane, and at the same distance from the needle, so that the poles of the two magnets looking in the same direction be cognominal; the needle will be directed toward the middle of the interstice between the magnets and in which lies the centre of the magnetic forces ; just as in the case of two separate bodies, the centre of gravity lies between them. But if the pole of the second magnet which was placed near the first, be of another name ; the needle observes a direction perpendicular to the axis of the two magnets ; for its point is attracted by one pole in the same degree in which it is repelled by the other.

EXPERIMENT LX.

Fig. 50.*

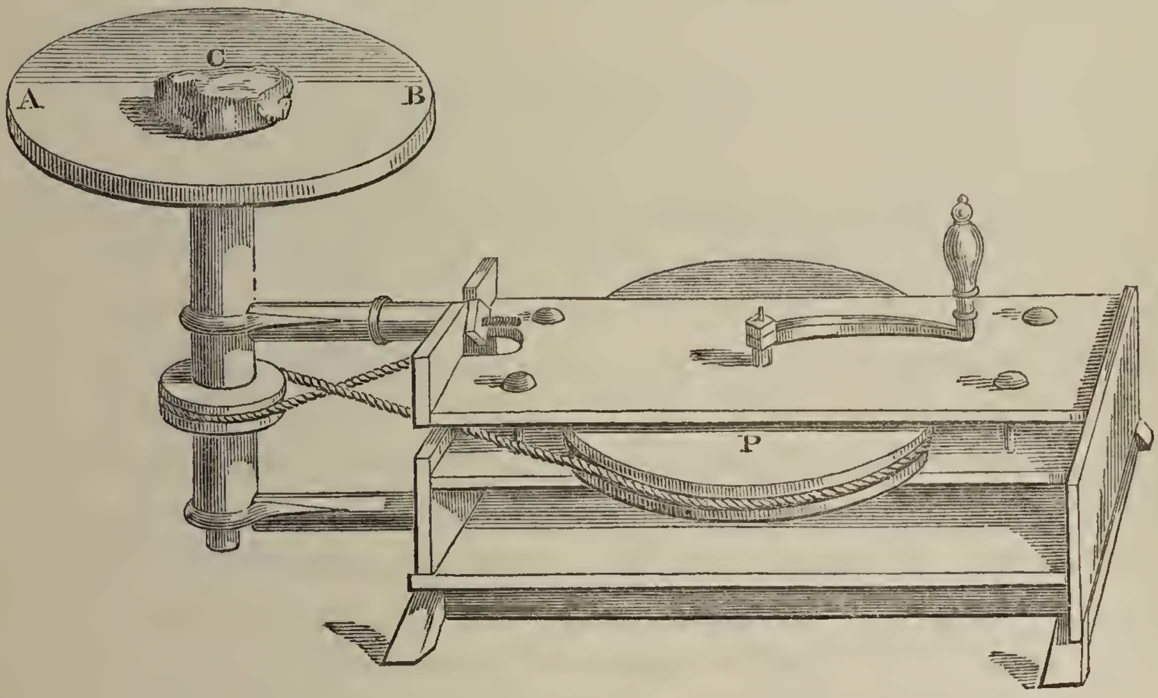


Fig. 50. On the table AB, which could be rapidly whirled round by the wheel P, was fastened the magnet C, having its axis perpendicular to the horizon and its north pole upwards. A magnetic needle was then placed upon another table which was immoveable, and in the same horizontal plane with AB ; this needle was also covered with a glass bell, lest it should be disturbed by the motion of the air produced by the gyration of the table AB. The needle was then moved so near the magnet C as to be within the sphere of its influence. The needle being at rest, the table AB was rapidly whirled round. At first the needle appeared to oscillate right and left ; for a while abandoning slightly its original position. But when the velocity of the table AB was increased as much as possible, the needle remained fixed in its meridian, nor manifested the slightest symptom of motion.

---

* In the original, plate XIII., fig. 1.

EXPERIMENT LXI.

All the apparatus of the preceding experiment remaining the same, the position of the needle was elevated, so as to be in the plane above the pole of the magnet C, whither the needle was immediately directed; being pressed also by the forces of the attracting pole downward. The needle was so placed that it might move from its meridian by the attraction of the magnet. The stone C being rapidly whirled round by the wheel P the needle continued to retain the same depression, quietude, and direction as before; so that this rapid gyration did not hinder the magnet from acting upon the needle.

EXPERIMENT LXII.

The same magnet C which was used in the two former experiments, was so attached to the table AB that both its poles, or its axis, lay in the horizontal plane ACB. The needle was placed upon another table which was immoveable, so as to be in the same horizontal plane with ACB. The magnet being rapidly whirled round, the northern point of the needle became inverted, and was directed towards the magnet; and remained in this situation immoveably, as long as the magnet was revolved with the utmost rapidity; but when its motion was slackened, the needle was observed to oscillate. The effect was observed to be the same, whether the needle was placed north, east, south, or west of the magnet; for the northern point was always attracted toward the magnet.

From this experiment we again learn, that the most rapid gyration of the magnet does not prevent the needle from being attracted. The northern point of the needle was directed to the magnet, because the southern pole of the magnet, against which the needle was rubbed, has in this part of the world a greater power of attraction than the northern.

EXPERIMENT LXIII.

The magnet attracts pure iron, as also that which is impregnated with force by a magnet; but it acts upon the latter at a greater distance than it does upon the former. The distances in which the action of the magnet upon impregnated iron begins to be visible, are to those of its action upon iron not impregnated, as about 5 to 2.

Whiston was the first to whose sagacity we are indebted for this observation. Iron therefore which is drawn over the magnet and is imbued with forces, is as it were in the centre of these forces which are diffused to some distance; and the forces of the magnet and of the iron meet each other, as it were, and act upon each other in the intermediate space; unless we suppose that iron which is endued with force is more mobile than the other, and therefore capable of being moved by smaller magnetic forces at a greater distance.

EXPERIMENT LXIV.

If a magnet of an homogeneous substance be covered all round with extremely fine iron filings, or with Indian dust, there will not be a point on its surface to which the filings will not adhere by attraction. They will however adhere in a larger quantity to the corners and poles, than to the lateral and plane parts of the magnet. Every point therefore of the magnet is attractive; but not in an equal degree.

EXPERIMENT LXV.

If iron filings be sprinkled thinly and equably over the plane surface of a body not very dense (not excepting even iron); and if a magnet be placed directly below the body, one of the poles being turned upwards; we shall observe at first a great number of the particles of iron join themselves together into the form of an oblong needle; and those will be erected perpendicularly over the surface which are directly in the region of the pole of the magnet. When the magnet is moved to the right along the length of the sustaining plane, all the parts of the filings fall to the left; when the magnet returns to the left, all the parts become raised and then fall to the right. The same effect is observable whichever pole of the magnet be turned upwards. After frequent motions of the magnet to and fro beneath the plane sustaining the dust, the filings become arranged into an oblong series.

Moreover, if the side of the magnet be turned toward the plane and be moved to the right and left, then the filings also become erected, and fall in a direction contrary to that in which the magnet is moved; they fall however a little obliquely, being attracted by the poles on either side more than by the meridian of the magnet.

If we move to the right and left the magnet below the plane, with one of its poles upwards, so that the filings come into an ordinate series; then, if the magnet be inverted and with the other pole upwards be moved again as before, the filings will indeed adhere, but in such a manner as to seem uncertain which way to turn or to fall; but if the motion of the magnet be repeated, they become erect, and fall in a direction contrary to that in which the magnet was moved.

If however we draw the magnet over the iron filings, that part of the filings becomes erect which lies beneath the magnet; but it follows the motion of the magnet; so that if the magnet be moved to the right, the filings fall to the right, and the contrary. The experiment may best be made by sprinkling the filings over thin metallic plates; as of old Lucretius seems to have done when he thus sings:—

> Exsultare etiam Samothracia ferrea vidi,
> Et ramenta simul ferri furere intus ahenis
> In scaphis, lapis hic magnes cum subditus esset,
> Usque adeo fugere a saxo gestire videtur
> Ære interposito, discordia tanta creatur.

Now Gassendi thought, that in like manner as in this experiment the particles of filings are erected and fall, so are the parts erected and ordinated in the solid iron which is rubbed against the magnet; therefore that in iron the parts lay to the left when the magnet was drawn over them to the right; and the contrary in the contrary case; just as in a corn-field the stalks lean all on one side in the direction of the wind, and then on the other when there is a contrary wind. To me, however, the parts of the solid iron appear to cohere too strongly to allow of such an ordination by the magnetic force. But even were Gassendi's view of the case granted, it does not enable us any the more clearly to perceive in what manner, from the situation of the parts of the iron, the force of attracting another piece of iron would follow; nor what a mere position would contribute toward giving a direction of the iron to particular quarters in the heavens; unless we called in to our aid the hypothesis of a fluid.

The foregoing phenomena however are easily explained, provided we first bear in mind that small oblong fragments of needles, instead of filings, placed upon a plane, become, when the magnet is drawn along underneath them, plainly erected in a similar manner; and fall in a direction opposite to that in which the magnet is moved. Hence the filings may be contemplated as a congeries of small but oblong fragments. Let a magnet be conceived as being directly underneath one particle. This particle will be erected perpendicularly upon the plane, and both its extremities become polar; of which, the one that is in contact with the plane is a pole of a different name from that of the magnet which there touches the plane; for it is only those magnetic poles which are not cognominal that attract each other. Now the superior extremity of the particle, is the pole cognominal with the pole of the magnet; and inasmuch as the cognominal poles of magnets repel each other, so are we to conceive this one also as repelled by the pole of the magnet. Let the magnet be now moved below the particle leftwards, it will then endeavour to draw along with it that extremity of the particle which is in contact with the plane; but which is prevented from following it by the roughness of the plane, and consequently remains in its former place; while the pole of the magnet which repels the superior extremity of the particle acts upon it obliquely, and indeed towards the right; consequently it will be driven to the right, taking an oblique position. When the magnet is moved farther on so as no longer to act upon the particle, the latter by its gravity will fall to the right. What we conceive to obtain with one particle, obtains with all; therefore when the magnet is moved to the left below the plane, the particles placed upon it will at first stand perpendicularly, and afterwards fall to the right.

When however the magnet is drawn along over the filings and the plane, every particle becomes perpendicularly raised; the superior extremity of which becomes a pole, having a name different from that of the pole of the magnet which it faces. Consequently it becomes attracted by it and follows its motion. When the magnet therefore is moved to the left over the filings, the particles fall to the left; the result being obviously the contrary to that which takes place when the magnet is drawn along underneath the particles.

EXPERIMENT LXVI.

Fig. 51.*

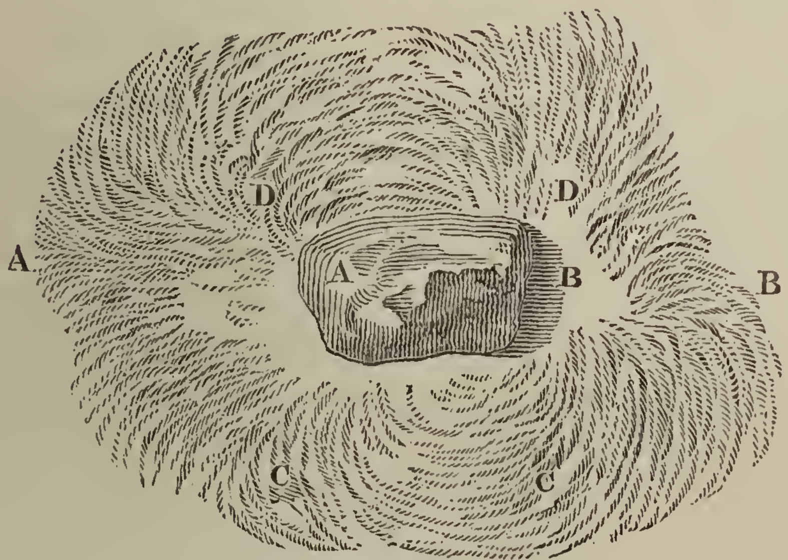


Fig. 51. If round the magnet AB, placed upon a plane, be sprinkled to some distance filings of iron, or rather Indian dust; and if the plane

be then gently tapped, the dust becomes disposed into ordinate oblong series, leaving intervals such as are presented by the figure. In these series are observable two quarters AA, BB, exhibiting for the most part rectilinear series; while others lie curved around each side of the magnet, as DD, CC, which are only portions of curves perpetually enlarged in proportion to their distance from the magnet. The series however do not all leave between each other an equal interval; but near the magnet are more contracted and about $\frac{3}{5}$ of a line of a Rhenish inch. The intervals are not altogether without an interspersion of dust, adhering in some series, and running out irregularly to the neighboring series. This however obtains more at a greater distance from the magnet than near it. These appearances may best be seen by placing a magnet over a glass speculum, under which lies some white paper; for there is no smoother surface upon which dust of iron or Indian dust can be disposed, or into a more ordinate series.

---

* In the original, plate XI., fig. 3.

Upon examining into these series, as arranged round the magnet, one might at first be disposed to presume that they resulted from some fluid flowing round the stone; and which, being conveyed in between the parts of the iron, disposed them into this regular order, when providing itself a channel, by removing those particles which served as obstacles to its course. On further attention, however, nothing will appear to be less true; for since the iron dust is extremely heavy and large, the fluid which would move it from its place and arrange it in order must be urged in a considerable quantity, with a strong and rapid motion, and possess great power. Consequently it will move, propel, disperse, or arrange the dust or lightest particles of bodies, such as flour, saw-dust, ivory-dust, dust of tin and copper, with greater facility than it will move extremely heavy particles of iron. Yet none of these sprinkled around the magnet are disposed into series, or put into motion; but lie in the state of rest in which they had fallen, just as if no magnet were present. How then can we conceive of a fluid which moves larger and heavier bodies, but is unable to operate upon the lightest? But suppose it be said, that the fluid does not flow in the intervals between the series but through the substance of the iron particles of dust; and that it is hence they receive their arrangement. Yet even if this be granted, how is it, I would ask, that the fluid does not move the lightest parts of flour, which it meets and penetrates; when it moves extremely heavy particles of iron? and secondly, how particles of iron can be arranged into a series leaving intervals between them, and not rather be arranged near each other? These difficulties no one can easily solve, until we better understand the nature of the magnetic forces.

EXPERIMENT LXVII.

Filings of iron were sprinkled over an iron parallelopipedon 6 inches thick, to whose inferior extremity a magnet was applied, and immediately the particles stood erect; a proof that the force of the magnet passes through even extremely thick iron.

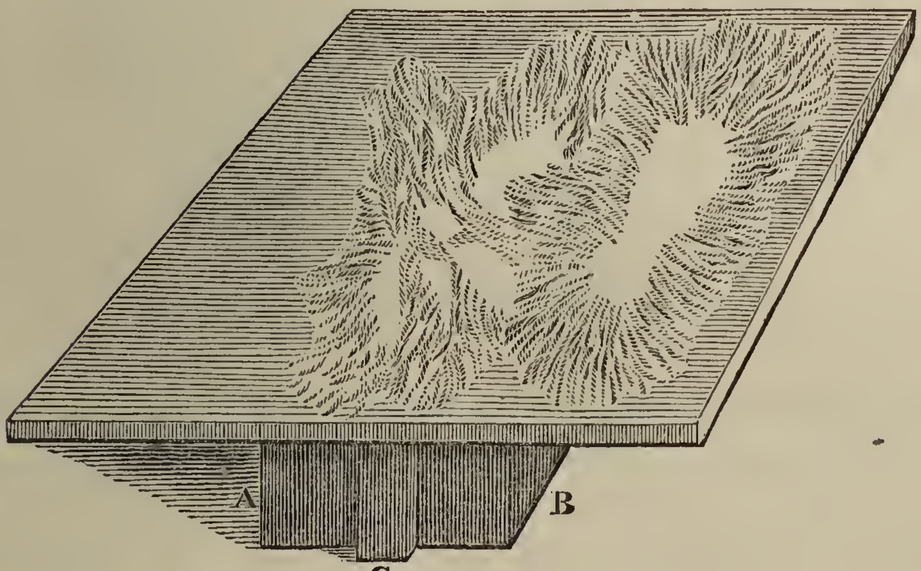
After this there were iron filings densely sprinkled over another iron parallelopipedon 1 inch thick. On this was placed the preceding parallelopipedon 6 inches thick, and iron filings were sprinkled over its upper part: the magnet was then applied to the lower parallelopipedon, and transfused its forces through the whole of this apparatus up to the filings sprinkled at the top; which caused them to stand erect as before. Whence the magnetic force not only passed through the solid iron, but also through the space between, nay, even through the disconnected dust into the solid mass.

EXPERIMENT LXVIII.

Let two magnets be placed near each other, so that the cognominal poles of both be upwards, and at the same altitude. On these let there lie a speculum of glass upon which iron filings are sprinkled; the latter then becomes arranged into the same series and forms produced by each magnet as before; except that in the place between the two poles there is a polar centre, or centre of forces, which is to be considered as one pole; while at a greater distance the magnetic force is seen to be diffused around; both magnets mutually assisting each other.

EXPERIMENT LXIX.

Fig. 52.*



---

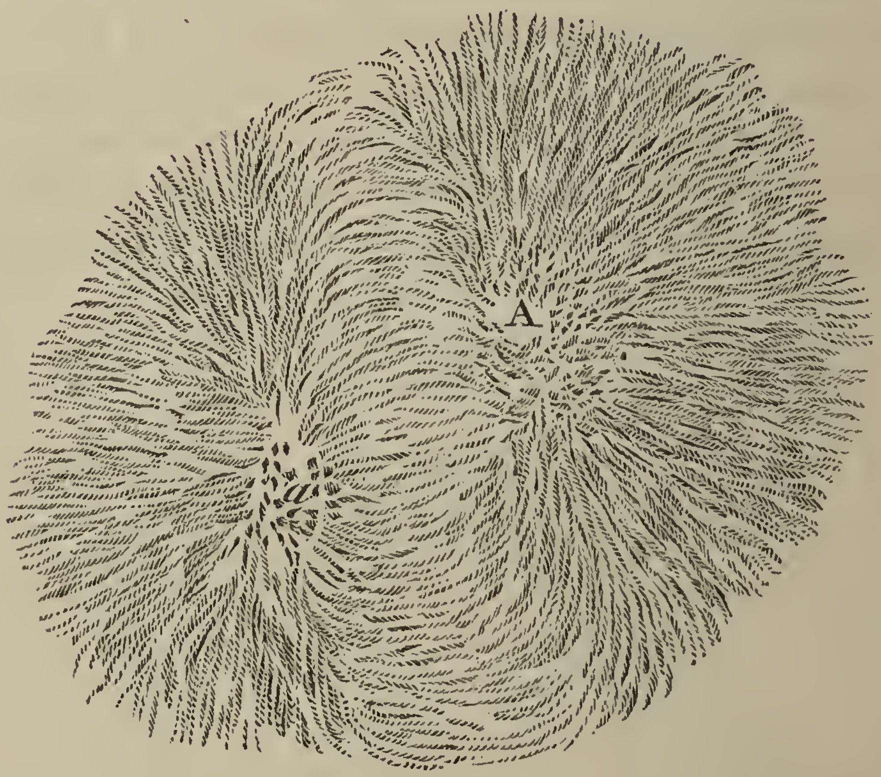
* In the original, plate XII., fig. 2.

Fig. 52. Let two magnets of a cubical form, and with their cognate poles upwards, whose superficies are plain and polished, be so joined together that between the two A and B may be the thin iron plate C. Let iron filings be sprinkled upon a tablet placed upon them; then will these become arranged into a series, represented by the figure; in which the polar place of the strongest magnet B is clearly indicated; but over the plate C are seen scarcely any filings, and beyond this place all is in disorder.

This experiment differs from the preceding, in consequence of the interposition of the iron plate C which produces all these irregularities of attraction; preventing both poles from conjoining themselves in the middle, and making one common pole for the forces: it causes however the forces of each magnet to remain distinct. But inasmuch as the magnet B is stronger than A, it the more strongly emits its forces to the sides which face it; forces which penetrating the iron fence disturb the order of the filings produced by A.

EXPERIMENT LXX.

Fig. 53.*



Let both the same magnets be located near each other without any intervening obstacle; but so that the poles of alternate name look upward. Over a little tablet [*asserculum*] placed upon them, let there be sprinkled iron filings; then will these, as in Fig. 53, exhibit both poles at A, *a ;* in the middle between which the filings will be disposed into a curvilinear figure regularly convex ; but inasmuch as there is all around emitted a force pursuing a rectilinear direction, it will dispose the filings likewise into a right line. Between the poles A, *a*, the figure of the filings is the same as if both magnets lying in the same horizontal plane faced each other with their poles of alternate name ; whence there is no repulsion of the filings, but an amicable attraction produced by the forces of conspiring poles.

---

* In the original, plate XII., fig. 1.

EXPERIMENT LXXI.

If filings of iron be poured into glass tubes, and be closely fastened in, they are equally receptive of magnetic force as a single undivided piece of iron ; as we learn from rubbing it upon a magnet, and then examining its magnetic forces ; for there is no difference between the two, except that the parts in the mass are united more closely than they are in the filings ; although in filings compactly arranged the parts are in a considerable degree of contact. If however the filings be shaken, so as to make the different parts change place, then all the magnetic force ceases ; for the parts are rubbed among each other in different directions. And as the iron was deprived of magnetic force, when rubbed against the same pole of the magnet in a direction contrary to the previous one, so by similar contrary frictions does the force disappear from among the filings.

EXPERIMENT LXXII.

Hitherto it has been evident, that the magnet attracts the iron ; but inasmuch as iron is a very compound mass, made up of sulphur, salt, and earth ; it remains for us to examine what it is in the iron which is attracted ; whether it be the sulphur, the salt, the earth, or all these together.

If iron be heated as strongly as possible in a coal fire, so as to be made to emit sparks ; if it then be taken out of the fire, and the spherical sparks which had vitrified be collected, then neither are these attracted by the magnet, nor do they in any manner deflect the mariner's needle from its course. Vitrification is the ultimate state to which any metal or body can be reduced ; this vitreous substance consists of earth ; but whether it possesses an admixture of anything else cannot be discerned. Consequently after the earth of the iron has been acted on by the greatest degree of heat, it no longer possesses a magnetic force, nor can be made to receive one.

The scoriæ, which fall from iron when hammered upon an anvil and are broad and smooth, are very powerfully attracted by the magnet; and after being once attracted, receive a force which they retain for some time. But when they are just taken from the iron and presented to a magnetic needle, they do not much act upon it, although they still deflect it from its position.

These scoriæ have undergone less combustion in the fire than the vitrified globules; they are however deprived of their sulphur and salt; consequently they no longer melt in the fire, nor burn; they contain therefore within themselves that principle or that kind of bodies which hitherto we have seen attracted by the magnet; and which, in a continued strong fire, is made to fly off before the mass becomes vitrified. Consequently that kind of body which is in iron and which is the only one attracted, does not appear to constitute any considerable portion of it; since the iron consists mostly of sulphur and of a copious matter which turns into glass. This substance however is very fixed; for it does not fly from the mass until the process of vitrification; a process which is effected only by the strongest fire which art can produce.

If now we could extract from the iron that only which is attracted by the magnet, then would this attract and be attracted most strongly; and the nearer we approach to this substance in its purity, the more strongly attractive is the mass we obtain. With this view I endeavoured to deprive the iron of all the matter which is not attracted by the magnet, in the following manner. I placed filings of iron at some distance from a needle 6 inches long, and gradually moved it nearer until I clearly saw the needle act upon the filings and become disturbed in its position. I then placed some filings in a small glass phial which I located in the same arc of a circle which the point of the needle described, and at a distance from it of half an inch. The point of the needle, in consequence of the attraction, adhered to the surface of the phial. The phial being at rest, I gently poured into it oil of vitriol, which dissolved the filings. After about two minutes the needle in some degree abandoned the phial, returning to its former natural position. The more the filings became dissolved, the more the needle receded from the phial. It never however returned exactly into its former position. The same result took place when I dissolved the iron in Glauber's spirits of nitre, or in common *aqua fortis;* the attractive force was always diminished, but never entirely taken away. From the solution of iron I prepared vitriol of steel; which, when well dried and presented to the point of a needle six inches long, attracted it but little; still the attraction was visible to the eye; the needle's point, receding from its former position about a quarter of a degree, as soon as the vitriol was held near. This experiment I repeated several times. At first I thought I had been led into error; as that acute observer Lemmerius, in *l'Hist. de l'Acad. Roy.*, A.D. 1706, had observed, that the vitriol of steel did not attract the magnet. Perhaps however he did not make the experiment with so long a needle as I did, but only with one of the common length; in which case the most experienced eye cannot observe any motion of attraction; a motion which is visible only when we use an extremely long needle. This force of attraction decreased from the filings when dissolved, for the reason that all the parts were removed from each other; and, being agitated simultaneously in different directions, like the filings shaken in the preceding experiment, consequently lost their force. The solution of the iron was first effected in order that the iron might be the more easily deprived of its sulphur; for sulphur adheres most powerfully to acid spirits, and together with these, by the aid of fire, readily flies off. From the vitriol placed in a retort I continued to elicit, by means of the fire, an acid spirit mixed with sulphur; until the matter resting at the bottom was of a red colour, commonly called the *colcothar* [*caput mortuum*] of vitriol. When the latter was presented to the forementioned long needle, it occasioned a motion, slight indeed, but greater than that which the vitriol alone had before produced. The acid spirit collected in a phial and applied to the point of the needle gave rise to no symptoms of attraction; whence I conclude that sulphur of iron is not the cause of the magnetic virtue.

I then placed the colcothar on a most vehement fire, having put it into an earthen crucible; and the result was a black and thin mass, in which there was no longer any sign of sulphur; as Lemmerius has correctly remarked. This was easily friable into dust; when thrown into the fire it emitted no sparks, as filings of iron do; and it seemed to be deprived of nearly all its salt, since it did not contract rust either in the air or in salt water. It scarcely affords a tincture: nor does it effervesce with oil of vitriol, spirit of salt, or spirit of nitre.

This mass, whether remaining whole or pounded to dust, is strongly attracted by the magnet and by the needle, and at a much greater distance than fresh filings of iron; a circumstance which manifestly proves, that neither sulphur nor salt in the iron is the matter giving rise to attraction; but that it is some other matter, which is attracted the more strongly in proportion as it is the more entirely deprived of sulphur and salt.

Hitherto this matter cohered with solid earth, which, as I before intimated, became vitrified and possessed within itself no attractive force. It required therefore to be separated from this inert earth as much as possible. In this respect I followed the example of Lemmerius, who poured upon this matter, first reduced to powder, spirit of nitre; in which case the powder became dissolved without any sensible effervescence; and at its surface turned into a white dust of a somewhat unctuous appearance; which for some time often retained a shining whiteness, sometimes was of a deep yellow. This dust being collected by itself, and nearly dried, was still more powerfully attracted by the magnet or by a steel plate, than the mass immediately preceding. This appears then to be the body which would seem to be the sole cause of attraction in the iron; and which, when mixed with other kinds of bodies so as to constitute iron, becomes in some measure impeded in its action.

Perhaps it is a similar or the same body which in the magnet solely excites attraction; and which, the purer and more copious it is, makes the magnet the stronger. This indeed may in some measure be inferred from those magnets which in process of time are generated in the air from iron; which, when it is corroded by the air into rust, mingles its salts with earthy matter. The sulphur is mixed with salts floating through the air, and therefore the component principles of the iron are of their own accord separated from it; namely, earth, the magnetic matter, salt, and sulphur. When therefore the magnetic matter, enters together with the rain, into the pores of stones in which the iron inheres, it changes them into true magnets, such as in the course of observation we are perpetually finding; provided the iron be for a long time exposed to the air, and be fixed within a stone of a spongy nature.

From this analysis we clearly see why steel is more endued with the magnetic force and retains it better than iron; for steel, before it is adapted to use, has often to be ignited and hammered; and it is clear that in the fire it deposits a considerable portion of its sulphur or oil; whence it is never afterwards so flexile as the iron; the steel therefore is then more depurated from the heterogeneous matter adhering to it, and in proportion to its mass retains more of the matter which is magnetical, and exercises a stronger attraction. Hence also we understand how iron may be endued with magnetic force the more, in proportion as it contains within itself the greater quantity of magnetic matter; and experience shews that all iron has not an equal quantity of it; since one piece of iron receives from the magnet a far greater power of attraction than another.

If vitriol of steel be rubbed against the pole of a magnet, it is imbued with a greater power, attracts the needle more strongly, and more displaces it from its position, than pure vitriol.

Boyle examined British ochre which is the rust of iron, but corroded by natural acid salts and mixed with earth, in order to see whether it exhibited any magnetic force; but he detected none. When however he afterwards committed the ochre to the fire, and expelled the sulphurous, saline, and several other parts, the residuary iron of the mass was enabled to exert attractive forces, with which it acted upon the mariner's needle; see his observations on the magnet, p. 499.

EXPERIMENT LXXIII.

At the commencement of this chapter we observed, that the magnet attracts with great force a certain species of sand which is of a dark color, shining, and never liable to rust. This sand is brought from Virginia, and is separated from its concomitant dust by the magnet. Its specific gravity as compared with common sand is as 161 to 71. I thought it worth while to ascertain whether this sand were iron or some species of iron; or whether it contained within itself no metal at all; for if the latter were the case, then it would shew that the magnet operates on other bodies besides iron. Molinus tested this sand in a variety of ways, and gave an account of the success of his experiments in the *Phil. Trans.*, no. 197. To these I have added other attempts which I thought would conduce to a better understanding of the subject.

1. This sand, if submitted to the fire and calcined, is after calcination more vehemently attracted by the magnet than before.

2. The calcined sand was mixed with charcoal reduced to powder, and placed upon a furnace [*fornaci probatoriæ*] for the space of one hour. It did not turn into *regulus*,* but was attracted by the magnet with a still stronger force than before.

The fire therefore only separates from the dust something which had a little impeded the attraction, but does not volatilize the matter which is attracted; although, as will be subsequently evident, it is capable of flying off.

3. The sand was mixed with fixed nitre, and was placed in a smelting furnace for the space of one hour; but did not change into *regulus*.

---

* The metalline part of minerals, which remains in the bottom of a crucible, after the separation of the scoriæ. *James' Dictionary.—(Tr.)*

The rest of the mass was not attracted by the magnet, with the exception of a thin crust which adhered to the coal thrown into the crucible.

4. After this it was mixed with nitre, and coal pounded to powder; but when, exposed for an hour to the action of a smelting furnace, it did not change into *regulus*. The mass thence produced was not attracted by the magnet, with the exception of those parts which adhered to the coal.

5. Another part of the sand was mixed with nitre and flour of sulphur; which, after having been for some time in the furnace, did not furnish any *regulus*.

Hence it is evident that nitre volatilizes that which in the sand is attracted by the magnet. It is in consequence of experiencing in itself the action of nitre, that it no longer experiences the action of the magnet.

6. From the following process however it is evident, that what is attracted by the magnet may be volatilized.

Three drachms of Indian sand were mixed with 3 drachms of ammoniacal salt, and exposed in an open crucible to a moderate fire; by which the ammoniacal salt was nevertheless volatilized and expelled: the entire residuum weighed 2 drachms, with 23 grains, and therefore the weight of sand that was lost was 37 grains; supposing that no salt remained in the sand. In the residuum the grains were larger than before, and of a beautiful cinnabar color. All the other parts lost their former blackness and verged toward an obscure red. Over these was placed and drawn the magnet, nay, it was even applied to them, but was scarcely able to attract anything; still there was an obscure attraction. The residuum was washed and sweetened with water, and dried; but was not attracted by the magnet more powerfully than before; a manifest proof that whatever was attracted by the magnet had escaped and disappeared from the sand together with the ammoniacal salt.

This substance however is not very volatile, nor does it ascend with the lightest parts of the ammoniacal salt; although with these there ascend from the sand certain parts of an orange color, as will be evident from the following process.

7. Three drachms of sand were mixed with 3 drachms of ammoniacal salt, which were enclosed in a phial and committed to a sand-bath for three hours; at which period nearly all the salt was sublimated, adhering to the sides and arch of the flask, and mixed with parts of the sand of an orange color. The matter left at the bottom was of a color from a deep yellow to a black [*ex fulvo atra*]; and on being exposed for some time to the magnet, was nevertheless but little attracted. The mass, when dissolved in water, afforded a thick tincture of a rusty

color; leaving a rather large-sized dust at the bottom. The solution was attended with a considerable effervescence. The tincture when dried was not attracted by the magnet. The dust which had subsided was large, consisting of several fragments which were hard, concrete, of a beautiful red color, and which, when dried by the magnet, were powerfully attracted. They were not yet volatilized by the salt, and therefore retained their attractive force; so that the ammoniacal salt did not immediately carry it off into the air, although it was now attacked with greater force.

From the foregoing operations, moreover, it is clear that this sand does not change into *regulus.* Whence we conclude that it has little or no metal within it, unless there be some portion of sulphur so firmly adhering to it that it cannot be absorbed by any force either of fire or of salts; and which prevents it from being reduced to a state of fluidity, and from turning into *regulus.* Is the presence of metal, however, required in a body, in order that the magnet should operate upon it? Surely not. Other bodies there are in which it has not been demonstrated that there is any iron, as I have above remarked, and which nevertheless experience the action of the magnet upon them. It is not altogether improbable, that in this sand is contained neither iron, nor any other metal; for it does not effervesce with spirit of sea salt, nor with the strongest spirit of nitre, nor with this diluted in water, nor with simple nor with double *aqua fortis,* nor with *aqua regia,* nor with strong oil of vitriol, nor with this diluted in water, nor even if the sand be calcinated or otherwise; nor, whether cold or hot, does it effervesce with the forementioned acid spirits, with which nevertheless it is known that all iron strongly effervesces. Can we therefore entertain the slightest suspicion that in this sand is latent any iron?

8. Three drachms of this sand were mixed with 9 drachms of minium, which were put into a crucible and exposed to a strong fire in a blast furnace for the space of three hours. These changed into a firm, exceedingly hard, and very spongy mass of an iron color, of an unequal surface; in which several portions of lead that were collected into globules firmly adhered to the other matter. Not the least sign was seen of any vitrification, the production of which was the object of the experiment. The result was rather that the minium returned into lead; for the substance, which by the aid of a knife might here and there be separated from the other matter, was pure lead. The other and harder portion of the mass, when pounded to dust, was attracted by the magnet quite as powerfully as the Indian sand; the dust however was less resplendent, and was not of so black a color; so that the lead could not expel the attractive forces from the sand. But since minium with

common sand or silex passes into a vitrified state, it is manifest that this Virginian sand is not an earth easily penetrated or soluble by this metal; which, when ignited, commonly passes through all other bodies. That nevertheless it is not a simple substance, we learn from the influence exercised upon it by ammoniacal salt and nitre. Of what more simple parts it is compounded I have not yet been able to find.

THE METHOD OF ARMING MAGNETS.

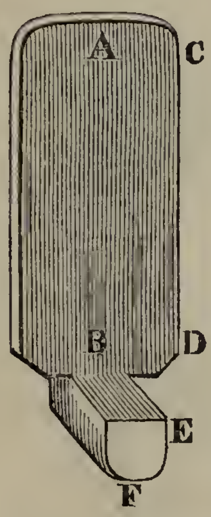
The magnet, when taken from the mine, is generally incapable of lifting or carrying any great quantity of iron; and therefore it is invested with an armature, by the aid of which it is enabled to carry a much greater weight of iron than it otherwise would; for this collects, directs, and condenses the forces which otherwise would be dissipated; and congregates those of the two poles, so that they shall act upon the same mass of iron, and attract it simultaneously. Of the various methods of arming the magnet, I have selected the best hitherto known; although it would be premature to affirm that it is the best possible.

Fig. 51 (p. 15). Let us imagine that we have here before us a shapeless magnetic mass, such as is taken out of mines; which has to be so armed as to make it raise and carry a considerable weight of iron. Let it be placed on a table; let iron filings be sprinkled round it; and let its position be shifted until it indicates two quarters, the one opposite to the other, arranging the filings into regular series. These two quarters will be the poles of the magnet; which will be determined with perfect accuracy if we place upon them a short and slender needle; which upon the poles stands perpendicularly, but is elsewhere obliquely inflected and attracted by the other sides of the magnet.

2. These two places which are found above the side on which it is made to turn, or above the plane of the rough stone, should now be smoothed and made even, so as to present superficies parallel to one another and perpendicular to the direction of the needle placed upon them. These superficies form the bases of the entire process; for, when these are duly prepared, the magnet is susceptible of any beautiful form we may desire to give it, whether cubical, parallelopipedal, or any other; for all the magnetic virtue is to be expected from the polar localities, and almost entirely depends upon them. We are here first to observe, that the magnet must never be curtailed after its polar places have been well smoothed; because the shortening always makes it lose some of its virtue. The other sides however round its axis may be

cut without detriment, as Vallemontius and many others have rightly observed.

Fig. 54.*



3. In the next place let there be provided of the softest iron, possessed of no pointed processes, several bodies of the form represented by Fig. 54.† Let ABCD be the thinner part having the same length and breadth as the entire polar side of the magnet to be armed. Let it have the thicker part EF inflected at right angles, and rounded off underneath or terminating in a prominence which is commonly called the *pes armaturæ.*

It is to be observed, that in the formation of this foot by the manufacturer, BE must be an inflected part of the iron AB, and that the channels of the iron striæ ABE must be continuous; for workmen, experienced in the art of making magnets, have observed that from the foot of the armature made in the manner we have mentioned, the magnet is capable of elevating a greater degree of weight. I have intimated that these bodies ought to be formed of the softest iron, and not of steel, as some have wrongly asserted; for magnets carry much more weight when the armature is made of iron, than when it is made of steel.

4. But what is the thickness required for the iron ABCD? This question is most difficult to be determined *à priori.* Let laminæ of different thickness and length AB be first drawn over the pole of the magnet, and let it be ascertained which is the one most impregnated with force. According to experiment 31 the thickness of this lamina must be the same as is required in ABCD. It is customary however to ascertain by successive trials from what armature most iron may be carried; for example, pieces of iron A, B, C, D, E, F, are made of different thickness; with these the magnet is armed; and those are selected which support the greatest weight. Others sprinkle filings over the plate AB applied to the magnet. If these be strongly attracted and be made to stand very erect, they infer that AB is too thin; if attracted slightly or not at all, they pronounce AB to be too thick; and that it requires attenuation until some of the filings become attracted.

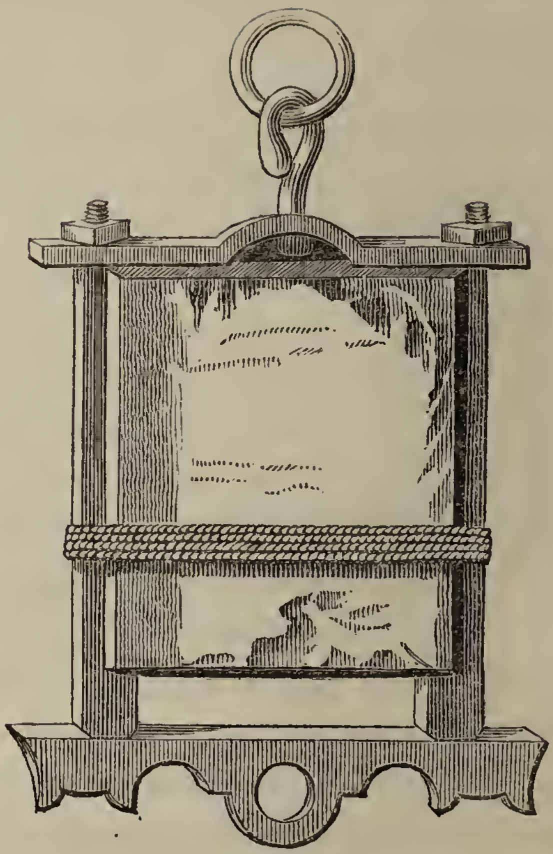
Let two iron bodies, of the same kind and nicely polished and smoothed, be applied to the magnet; one to each polar side. Let the foot BE also be in exact contact with the inferior part of the magnet. Let both be closely fastened to the magnet, which, thus prepared, is said to be armed; as in Fig. 55. By this method nearly all the force of the magnet proceeding straight from the poles, enters into the armature, is directed to the foot EF; which, being a little rounded off underneath, condenses the force into a narrower space; in which it lies, as it were, concentrated, and from which therefore the greatest weight will be carried.

---

* In the original, plate XI., fig. 4.

† This figure is slightly corrected from the original, in order to answer more exactly the description given in the text.

Fig. 55.*



Another form of armature is described by Gassendi and Cabæus in the *Philosophical Magazine,* book iv., chap. xliv., p. 408; which is produced by perforating the magnet through its axis, and passing through it a steel rod nicely fitting into the cavity. This rod will from its extremities exercise considerable power, still I would not advise any one to perforate a good magnet in this manner; because a great portion of the magnetic virtue is scooped out, and a weight can be carried only at one extremity of the transmitted rod; for in this case the two poles do not assist each other as they do in the case we have before described.

In the magnet we find various anomalies, not easily explained by any one so long as we know not what constitutes the magnetic force. The following are some, which, according to Hartsoeker, were observed by Butterfield. Some magnets there are which appear to act better when unarmed than when armed; for when armed they disappoint expectation. Again, some there are which when unarmed appear to be extremely feeble; while those which are armed possess considerable virtue. May we presume then that the force of some magnets passes through the iron easily; while that of others passes with difficulty? or that it depends upon the different nature of the iron? This subject has not yet been sufficiently attended to, and consequently with regard to it we cannot arrive at any certain conclusion.

---

* In the original, plate XI., fig. 5.

EXPERIMENT LXXIV.

The magnet, when armed in the manner we have described, attracts and sustains iron of much greater weight when applied to its feet, than when unarmed it raises at each pole.

For I have a magnet which unarmed sustains from each pole about 5 ounces of iron, and therefore would sustain from both together only 10 ounces; while the same magnet when armed raises 7 pounds of iron.

As a confirmation of my observations by the testimony of others, I may remark that Mersennus mentions that he saw a magnet weighing 3 pounds, which unarmed raised only half an ounce [*unciam semissem*], but when armed carried 10 pounds.

De Lany, in *Magist. Nat. and Artis,* vol. iii., book 23, chap. i., sect. 15, says, that he had a magnet, which when armed would lift about 864 grains, but when unarmed only 54 grains; and he mentions that there was a magnet at Rome which when unarmed lifted scarcely a drachm, but when armed lifted 5 ounces. From these observations it is evident, that a greater weight was carried by the armature than by the naked magnet; but inasmuch as we can scarcely think that these magnets were armed in one and the same manner, and with the greatest caution, so it cannot be pronounced that the forces acquired in lifting the iron were either in the same, or in a different proportion.

EXPERIMENT LXXV.

If a magnet be able to keep suspended from one of its poles a given number of iron rings freely hanging from it, but if one of them be so suspended as to touch simultaneously both poles of the magnet, then this one only can be sustained by the magnet and all the others which are applied to it fall.

At first sight we might have thought that the united force would be stronger; for since one pole raises several rings, it might be inferred that two poles would raise more; especially since a much greater weight of iron can be suspended from both poles than from one. But we find the contrary to be the case. The reason therefore of this incapacity will depend on the annular figure of the iron itself, which causes the force issuing from one pole of the magnet to destroy that which proceeds from the other, after they have met each other in a contrary direction, so that no more can be carried by the first ring.

EXPERIMENT LXXVI.

If an iron plate be rubbed against the foot of an armed magnet, it is imbued with a greater power of attraction than if it were rubbed against the same pole of the magnet unarmed.

This has been controverted by some who maintain that the same force is communicated by an unarmed as by an armed magnet. I cannot however agree in this opinion, contrary as it is to experience. Nay, does not reason itself militate in our favour? For since the magnetic force is concentrated in the foot of the armature, so that much more iron is carried by it than can be by the magnet itself, does it not follow that so much the more virtue will pass into the plate when rubbed? as is commonly the case with a stronger magnet.

EXPERIMENT LXXVII.

If an iron plate adhere to each foot of the armature, and if there be in the same plane with the armature and the plate, a mariner's needle distant from the magnet and lying in a perpendicular between the two feet, the needle will not be moved by the magnet at so great a distance as if the magnet were unarmed, or the armature did not carry the plate.

That such is the case is because the force of the magnet operates upon the plate applied to the feet; whence it does not become extended to so great a length as it would if there were no iron plate.

EXPERIMENT LXXVIII.

If iron be rubbed longitudinally and simultaneously upon each foot of the armature, it does not acquire so great a force of attraction as if rubbed only upon one foot.

Inasmuch as iron acquires from each pole contrary forces of direction, which destroy one another, there remains only a smaller quantity of these forces in the iron. Wherefore in order that the iron may be imbued with any considerable force, it must be rubbed only upon one pole or foot of the magnet.

EXPERIMENT LXXIX.

The attractive force of different armed magnets in raising an iron weight is, *ceteres paribus,* in the duplicate ratio of the diameters, or in the ratio of the superficies.

Whiston in his treatise on the Dipping Needle, p. 11, mentions this as the proportion found by the celebrated Paisley; for since the force issues from the surface of the magnet, the larger the surface occupied by the armature the greater the quantity of forces it receives from the magnet, and the greater weight of iron will it carry. Hence we see how much the magnetic force differs from gravity, which is in the ratio of the density of bodies, or in the triplicate ratio of their diameters. It is evident therefore that the force of the magnet cannot depend upon that law of nature by which, in the case of two bodies, the one approaches the other; for then the force would be in the ratio of the quantity of matter; that is to say, it would be as the gravity; whereas on the contrary it is now seen to be only in the ratio of the surface of bodies.

EXPERIMENT LXXX.

An equal force of two good unarmed magnets, not sensibly unequal in power, and like in figure and position, but of unequal magnitude, is sometimes a little greater or less than in the ratio of their diameters.

Whiston also remarks that he had learned as much from various experiments; he confesses however that there is great difficulty in determining whether different magnets, or different parts of the same magnet, are equally good; inasmuch as it is commonly impossible to succeed with exactness in the experiment.

A magnet is generally endowed with two poles, which are places of some breadth, and not mathematical points like the poles of the earth, or of the heavens. We have above mentioned, that the greatest attractive force of the magnet is exercised by these poles. These consequently are easily discovered, by applying the iron to the magnet on different sides, and ascertaining what are the places in which it is most strongly attracted. They are most easily discovered however by the sprinkling of iron filings, or by drawing around it a mariner's needle placed upon a moveable pin; in which case the needle flies towards the poles with the greatest impetuosity.

Sometimes the two poles are diametrically opposed to each other in a right line; sometimes also in a curved one. Moreover we do not in all magnets find necessarily only two poles; for I have myself seen, and other authors also have observed, magnets in which there are three poles, as Fournier likewise has attested; as also magnets which have manifestly four poles. Pugettus in his *Treatise on Magnetic Experiments,* written in French, makes mention of a spherical magnet (Fig. 56) ABCD standing upon an ivory foot, by whose pole A the point of a mariner's needle is attracted, and by the opposite part C is also attracted; a proof that A and C are cognominal poles. By B was attracted the tail of the same needle, which also the opposite point D equally attracted. A celebrated maker of mariner's needles at Rotterdam, of the name of Dykgraaf, possesses a magnet, which he lent me for examination, of a cubical form, as represented in Fig. 57, in whose anterior side NZ are two poles, one of which N is the north, and the other Z the south. The side NZ opposite to the former‡ has also two poles; one of which N is the north, and the other Z the south. In the possession of the same mechanic is another magnet of an oblong form (Fig. 58) in which were first observable three poles; one B the north, and M, M, two south poles; but when the magnet was divided by the section FK the fragment BMKF was observed to have four poles; two north B, B, and two south M, M. I have examined another magnet which, in almost every point of its surface, seemed endowed with a pole, and exercised in every direction an equal force of attraction; magnets of this kind however are anomalies. Only a small number of magnets have their two poles directly opposite one to another. On regular magnets I shall again have to treat in the sequel.

Fig. 56.*

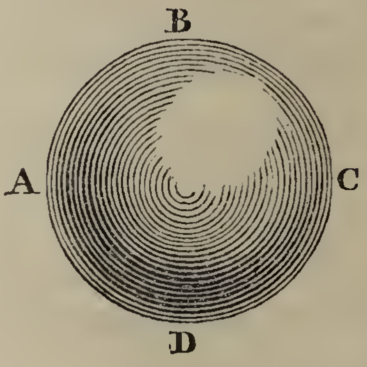


Fig. 57.†

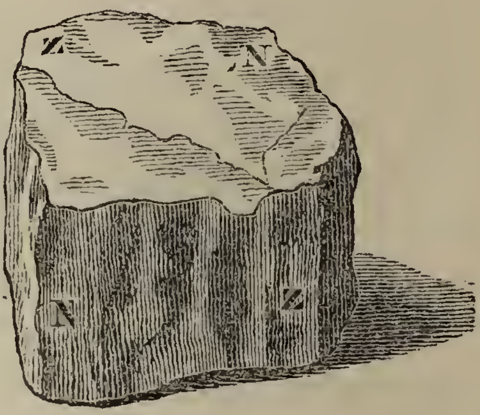
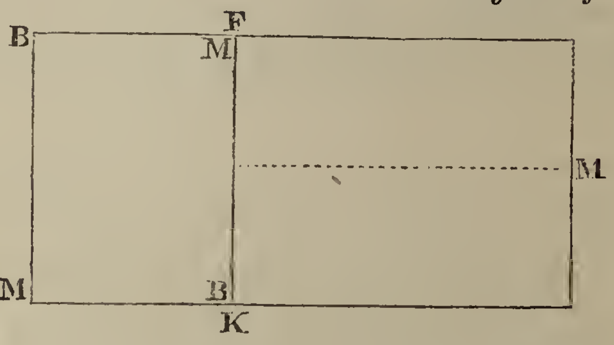


Fig. 58.§



---

* In the original, plate XIV., fig. 1.

† In the original, plate XIV., fig. 2.

‡ The letters NZ are supposed to be on the opposite side as mentioned, and not on the upper surface as they appear..

§ In the original, plate XIV., fig. 3.

EXPERIMENT LXXXI.

If a magnet be placed in a small wooden boat floating upon the water in a large vessel, and if with its axis it be parallel to the horizon; it will turn itself until its poles face determinate quarters of the heavens; one of which in this region will be toward the north, the other toward the south.

Those persons speak but incorrectly, and have made but inaccurate observations, who affirm that the magnet turns directly to the north and south; for in the sequel it will be evident, that there are only few places on the surface of the earth in which the magnet points exactly in these directions; since there are only three meridians of the kind hitherto known. It is sufficient for our present experiment simply to mention this circumstance: in the sequel we shall speak of it more at large.

It is not requisite that the magnet, whose direction we have to examine, should float in a boat; for the same result occurs if the magnet be suspended from a fine silken thread not twisted but woven, and having its axis parallel to the horizon. Nor is any difference observable whether the magnet be great or large, integral or divided into parts; for all its particles are acted upon in the same direction.

Definition. *The pole of the magnet which always turns toward the north is called the north pole, but the one which turns toward the south is called the south pole.*

Scholium. It is uncertain at what time it was discovered that the magnet, as also iron drawn over it, points toward the north and south quarters; as also at what time it began to come into use among mariners, and at what time the needle was brought into the present form of the compass, and accommodated to maritime uses. It is probable that at first some one accidentally found that one pole of a needle, placed in a little boat and swimming in water, was constantly directed toward the north and the other toward the south. Next that iron rubbed upon the magnet and placed in a similar boat was turned in the same direction; that afterwards the iron was placed on the point of a pin so as to be able to move more freely and rapidly; that next the question arose whether it would be of any use to mariners, so that when the sky was covered with clouds and neither sun nor stars were to be seen, mariners might be able to distinguish the north and south poles, and thus direct their course safely over the seas; and that the defectiveness of the plan of placing the needle solely upon a pin, observable on any concussion of the vessel, gave rise to the mariner's compass, and thus that the invention arrived by degrees at its present state of perfection. This at least is the ingenious conjecture of Wallis in the *Philosophical Transactions*, n. 278.

The use of the compass at sea seems to have been first known to those inhabitants of Gaul, who occupied the shores of the Mediterranean; but what individual was the first on board of ship that began to use the compass, and at what time, is unknown. The needle however was known before the year 1180, A.D.; because there then lived and wrote a Gallic poet of the name of Gujot of Provence, who called the compass a marinette, and an unerring piece of workmanship; his verses are as follow: *Icolle estoile ne se muet, Un art font, qui montir ne peut, Par vertu de la marinette, Une pierre laide, & noirette, Ou li fer volontiers se joint.* These verses may be found in Fauchet's *Antiquities of France*, or in Perrault's *Parallele des Anciens & Modernes*, vol. iii.; also in Gassendi, book x., *Diog. Laert.*, vol. i., p. 193, who also in demonstrating it to be an invention of the Gauls, argues that the mariner's needle is adorned with the lily, which is the insignia of the kingdom of the Gauls. This invention crept along the shores of the Mediterranean, and thus came to Venice; where it was first brought into notice by Paul, a Venetian, to whom therefore is ascribed the credit of the discovery in the year 1260. It was also taken to the city Amalphis, in the kingdom of Naples, where it was first brought into use by John Goya, about the year 1300, whence the verse,

> Prima dedit nautis usum magnetis Amalphis.

To those two were assigned the credit of the invention by their respective countrymen; undoubtedly only because they were the first in their own country who used the compass, which for a considerable time previously had been known to the Gauls.

EXPERIMENT LXXXII.

If a magnet, placed in a small wooden boat to prevent its sinking, have its axis perpendicular to the horizon, and float in a large vessel; it will always turn the same end northward and the other southward.

Fig. 59.*

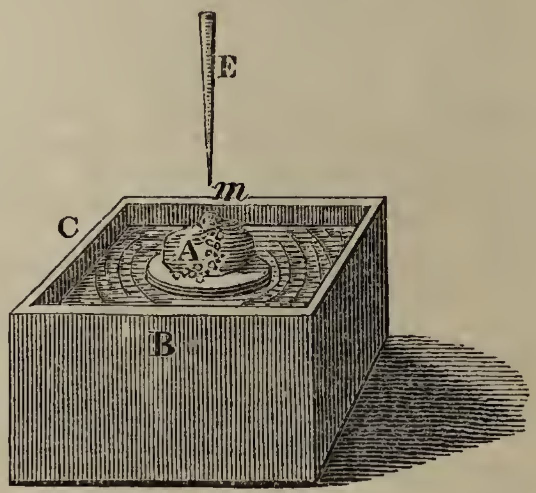


Fig. 59. Let the magnet A floating in a boat in a vessel full of water CB face the zenith with its south pole m. Over the middle of the vessel let there be suspended the iron needle E upon which the magnet acts, in order to keep it in the middle of the vessel with the greater facility. Let the part of the magnet be noted which looks to the north when the mag-

net is left to itself; then let it turn again, and, when left to itself, it will present as before the same side to the north, as Grandamicus first observed.

---

* In the original, plate XIV., fig. 4.

EXPERIMENT LXXXIII.

Fig. 60.*

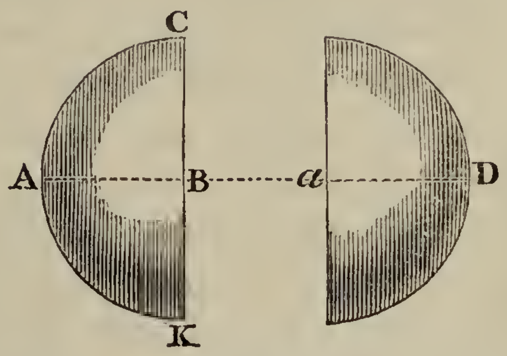


Fig. 60. Let ACDK be a magnet whose two poles are A, D, and consequently whose axis is AD. Let the magnet be divided at CK by a section perpendicular to the axis; then will the pole of one segment A, which before was the southern, be still southern; and B will be the northern: also the part *a* of the other segment, which adhered to the north pole B, will be a south pole, and the part D a north pole as before.

This experiment has been controverted, and requires therefore another and more accurate examination. Any one who is not in possession of magnets of little value, or who is not clever in the art of separating them, may institute the same experiment with iron wire which has first been drawn over the magnet; for, when divided into parts, it will exhibit the same phenomena. Del Porta in his *Magia Nat.*, and afterwards Ridley in his *Treatise of Magnetic Bodies,* chap. ix., affirm the contrary; maintaining that after the section the south pole A will be changed into the north. Whether this really occurred to them I know not, but I doubt it; for the contrary happened to me, and I find on my side Gilbert, book ii., chap. v., on the *Magnet,* as also Barlow in his *Magnetical Advertisements,* chap. ii. Nevertheless neither Del Porta nor Ridley can be accused of stating an untruth; for perhaps when they made this experiment they split the magnet with a wedge, and by subjecting it to a considerable violence, changed the directive force of the magnet. For I have observed, that when with a file I have slowly but completely cut the iron into parts, in all the segments the directive force remained the same; but when, with a file, I had separated the parts of the wire only to the middle, and broke off the rest by twisting it, or when I had cleft it with a chisel and hammer, the south pole changed into a semiboreal, and sometimes entirely into a boreal; whence it happened that a segment of the same kind had two north poles at its extremities.

---

* In the original, plate XIV., fig. 5.

EXPERIMENT LXXXIV.

Fig. 61.*

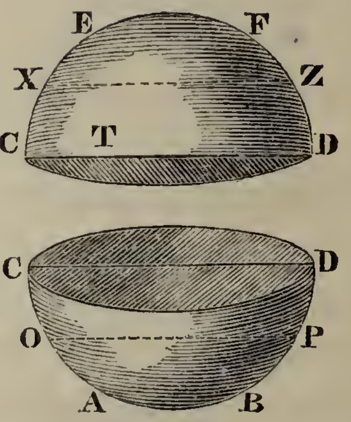


Fig. 61. Let CD be the axis of the round magnet ABEF, C the south pole, and D the north pole. Let the magnet be divided by a section through the axis; then the segment COABPD will have its south pole in O, and its north pole in P; the segment CXEFZD will have its south pole in X and its north in Z.

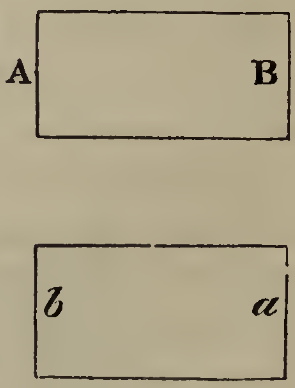
These segments therefore retain the same poles with which they were before endowed; the only change is in the axis, which becomes XZ and OP, passing through the middle of every segment. The same obtains in every section parallel to the axis. It is therefore evident that the whole of the side EXCCOA is polar, and constructed in the same manner. But it might appear as if certain quarters such as C and D were the only poles, when nevertheless every point in the side ACE or BDF is polar; but in the entire magnet the poles C and D were concourses of forces, or a centre of poles on each side.

EXPERIMENT LXXXV.

Fig. 62.†

Fig. 62. Of the two magnets AB, *ab*, let the south poles be A, *a*, and the north poles B, *b*; these, if placed in the same horizontal plane, are enabled to approach each other; the north pole of one will attract and adjoin to itself the south pole of the other; therefore (Fig. 63) the magnet AB if held over the other *ab*, will, if each be able to turn freely, turn in such a manner that the south pole *a* will be directly under the north pole B, and the north pole *b* under the south pole A.

Fig. 63.‡



Nor let this circumstance occasion surprise; for it will be evident to any one who contemplates the magnet, which before was a whole but is now divided into parts, that the parts of the whole were put together in this very order. For if the two magnets AB, *ab*, had before constituted one mass, would not the part *a* have adhered to the part B; and these two parts have attracted each other? When therefore they are separate, as in the present case, will they not do the same? Thus will the poles of alternate name conjoin themselves together; while the cognominal poles, such as the two north or two south, will mutually shun each other; since these have never naturally cohered in the magnet.

---

* In the original, plate XIV., fig. 6.

† In the original, plate XIV., fig. 7.

‡ In the original, plate XIV., fig. 8.

EXPERIMENT LXXXVI.

Fig 64.*

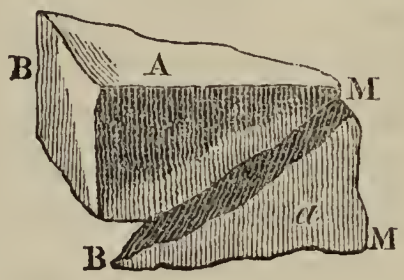


Fig. 64. Let A, *a*, be two prismatical magnets; the south poles of which are MM. Let the north poles BB be so made that one of them terminates in a point. Let both magnets be joined together so as to constitute one parallelopipedal mass. This mass will have two poles, and an axis passing through its middle.

From this experiment it is again evident, that the polar quarter of the magnet is only a collection of poles. Also that the pole is the centre of their forces. So that the whole force of the pole B of the inferior magnet approaches toward the pole of the superior, which also approaches toward that of the inferior; and thus both poles coalesce into one situated in an intermediate place of the side BB.

EXPERIMENT LXXXVII.

Let an homogeneous spherical magnet be placed upon mercury, so as to float freely; but with its axis parallel to the horizon. If left to itself it will move from its horizontal position; inclining its north pole, in this region, downward, and raising the south pole. This inclination varies every year in the same region, and in the same year in different regions; as will be more clearly seen in the sequel, when treating of the experiments made with the mariner's needle.

EXPERIMENT LXXXVIII.

If an oblong magnet be for a short time submitted to the fire, so as just to acquire a red heat; then if it be placed perpendicularly to the horizon and allowed to cool, its lower extremity will in this region become the north pole. We shall have occasion to observe in Chap. V., that the same occurs in the case of iron when left to cool in the same position.

---

* In the original, plate XIV., fig. 9.

EXPERIMENT LXXXIX.

If an oblong magnet be ignited, and placed perpendicularly upon the northern pole of a stronger magnet, and be allowed to cool in this position; the ignited magnet will acquire considerable virtue from the stronger, and its inferior pole will now become, not northern but southern; and will impetuously attract the north pole of the mariner's needle. If a magnet, before it is committed to the fire, be feeble; then, if as long as it is hot it remain placed upon a stronger one, it will become endowed with considerable strength, and greater than it had before. The celebrated Boyle observes, that he had examined a magnet which when cold scarcely lifted a small segment of a needle; but after being made red hot, and placed upon a strong magnet on which it remained till it was cool, it then carried considerably more iron. If a weak magnet, when cold, be placed upon a stronger, it acquires an increase of its forces; but not so soon, or in so great a degree, as if the magnet when ignited were placed upon another.

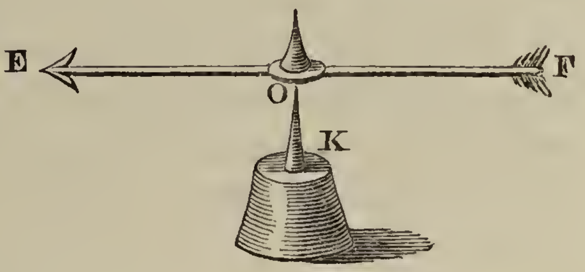
The fire by rarefying the magnet removes all the parts one from the other, and makes them less cohesive, for it renders the hardest metals fluid; and therefore a strong magnet placed beneath another ignited, consisting of parts easily displaceable and located in a different order, so agitates, arranges, and directs the parts of the latter by penetrating them with its virtue, that they afterwards possess a much greater power of attraction. A cold magnet however does not consist of parts so easily moveable, and capable of being disposed in a different order. Therefore the parts of a cold magnet placed upon a more powerful one, are not so easily changed or arranged in a different manner; nor can they be impregnated with so great a degree of force.

By adopting this method we are enabled first to convert the poles of magnets; and secondly, to weaker magnets to impart more strength.

The foregoing are the primary phenomena which magnets exhibit in regard to the direction of their forces. Others I purposely omit; both because they appear to be of little moment, and because I do not wish to be tedious; desiring rather to pass on to an investigation into the direction observed by iron, which will supply us with more accurate observations. I enter into no explanation of the manner in which the phenomena happen; preferring as I do to subjoin the theory of Halley, with a few annotations; and if these be understood, we shall see what opinions ought to be held on the cause of the direction of magnets.

Definition. We shall call by the name of needle, the magnetic or mariner's needle. Fig. 65. If a steel needle EF be furnished in its middle, O, with a little brass head, hollowed out underneath and placed upon the copper pin K, so as to turn round upon it freely; then the point E we shall call the head of the needle, and F the tail.

Fig. 65.*



EXPERIMENT XC.

If the extremity of a piece of iron wire be placed upon the pole of a magnet, not so as to rub it, but only to apply itself and then to pull the magnet, the wire will throughout its whole length exhibit certain magnetic polar points in different places, which are called consecutive points [*puncta consequentia*], because they attract alternately the north and south pole of a needle, whose apex is moved slowly along the wire to the distance of half an inch.

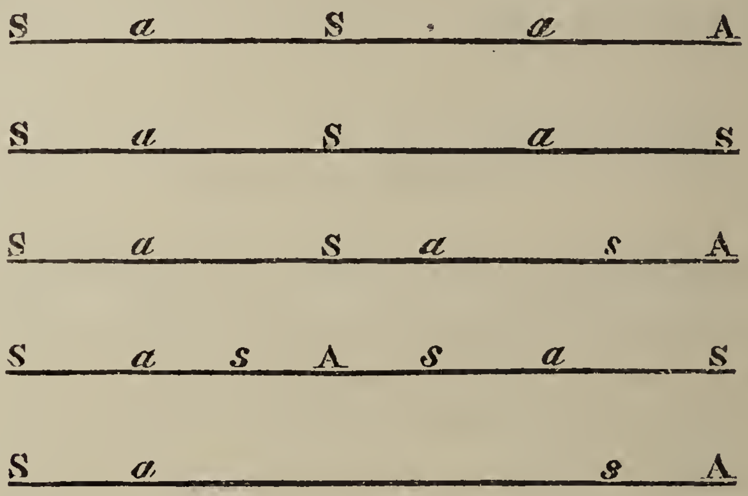
I took a new needle, which I had just before submitted to the fire, and which was not yet impregnated with magnetic force. This needle was 12½ inches long; and I used it in place of the wire and iron rod. When balanced upon a pin, it was extremely mobile and became disturbed by very small magnetic forces. Over this I held, and along its length I drew, the northern apex of a needle which had been rubbed against a magnet; and I then observed six consecutive points. The apex of the new needle was attracted; while a place distant thence 1½ inches was repelled, and was 6 inches long. There was yet another attracting place and another repelling; the next place to this was attracted, and lastly again the other extremity was repelled. But when the southern apex was drawn along the length of the new needle, there were observed only three consecutive points, and in places different from those in which they were before observed. For the extremity of the new needle was repelled; this repulsion continued along a space of 1½ inches; then followed a slight attraction, extending almost to the extremity; and after this a very powerful attraction distinct from the former. These phenomena were all much more clearly seen, after the apex of the new needle had once been applied to the pole of the magnet.

---

* In the original, plate XV., fig. 9.

The first persons who described this experiment, were the celebrated Desaguliers and Taylor, in the *Philosoph. Trans.*, No. 368. The latter took five common steel needles 2 inches long, (the extremities of which had before been applied to the magnet,) and placed them upon stagnant water; he then moved the head of a magnetic needle along their whole length, yet so as not to touch them, and then the south or north pole of this needle was attracted by the points marked in Fig. 66, and indicated by the letters A and S. In the first needle were observed five poles; as also in the second; between which there was only this difference, that both the extremities of one attracted the north pole. In the third were 6 poles, in the fourth 7, in the fifth 4.

Fig. 66.*



Do not these phenomena depend on spines of iron abounding in a greater or less number, and intersecting as it were the iron, so as to divide it into various fragments, at whose different extremities are different attracting poles, stronger or weaker according to the structure and situation of the spines? This indeed is probable; for it is evident that in all iron and steel there are spines which are indeed iron, but harder and different from the rest; and sometimes as distinct from it as a knot in wood from the rest of the grain. These spines being placed in no order, the consecutive points do not observe equal or proportional distances from them.

EXPERIMENT XCI.

The middle of a new needle 12½ inches long was placed upon the south pole of a magnet: when drawn away its head was directed to the north, and its tail to the south. 2. The north part of this needle, placed at its middle over the south pole of the magnet, was then drawn from the middle toward its northern extremity, for a length of about two inches; the needle was then placed upon a pin; but its northern extremity observed scarcely any direction, the needle being torpid; still it pointed to the north, and when the northern point of another needle was drawn along its length, only two poles were observed; one of which being very torpid was the north, at a distance of two inches from which the entire length of the needle was attracted by the north point of this other needle; its southern point however was not torpid, but most strongly attracted. 3. The middle of the same needle was next placed on the south pole of the magnet, over which the north part of the needle was drawn to the place where a consecutive point had just before been observed, but not to the extremity. In this case the direction of the needle was the same as before, but it was observed to move with much more vivacity, and to have no more than two poles, one at each extremity; the force of each terminating in the middle of the needle.

---

* In the original, plate XII., fig. 5.

4. All the phenomena were the same when the middle of this needle was placed upon the south pole of the magnet, and the northern part of the needle was drawn over it to its apex.

5. The middle of the needle was again placed on the south pole of the magnet, and the south part of it was drawn for some distance toward the extremity from the middle. The needle now began to grow very torpid, observing scarcely any given direction, and declining for the most part from the magnetic meridian. The point which before was northern still continued so; but four poles were observed in the needle, two consecutive to each other in the north part, and two others consecutive in the south.

6. The middle of the needle was again placed upon the south pole of the magnet, and when its south part was drawn over the pole to a distance of 1½ inches from the extremity, the needle turned upon the pin, and the extremity which before was south now became north. Each extremity however was repelled by the northern point of the other needle, and now three consecutive points were observed.

All the phenomena remained the same as in art. 6, after the half of the needle, namely, the southern, had been drawn over the southern pole of the magnet; and each extremity was still repelled by the northern point of the other needle.

In these experiments it is evident, first, that the consecutive points which are found in a long needle, are more or fewer according to the different manner in which the needle is drawn over the magnet. 2. That the same pole of the magnet may impart to the needle two opposite directions, according as the latter is drawn from its middle to the right or left over the magnet. 3. That the part of the needle applied last to the magnet is endowed with greater forces than the other part; because it was for this reason that the needle turned in art. 6 and 7. 4. Hence we see the error of the rule maintained by many of the learned, that the north pole of one needle always attracts the south pole of another; for there are many instances in which the south pole of one needle is repelled by the north pole of another, as we have already seen in our experiment. Hence, book i., c. 6, Gilbert undeservedly opposed the great Albert, who said that in his time a magnet was found which with one pole attracted a piece of iron, and with the other repelled the contrary extremity of the iron, when it ought to have attracted it. This however was perfectly true, if in the experiment made by Albert he employed a needle such as our own.

EXPERIMENT XCII.

Whether it be the upper or lower, the anterior or posterior, lateral surface of the needle that is drawn from the middle to the extremity, and whether it be drawn to the right or to the left over the same pole of the magnet, the same phenomena are observed in regard to direction and consecutive points as in the preceding experiment.

EXPERIMENT XCIII.

The magnetic force being wholly expelled by the fire from the needle employed in the preceding experiments, we found nevertheless that on cooling it had acquired a directive force by which its head became directed toward the north and its tail to the south, as we shall explain more at large in Chapter V. The needle however now exhibited a polar force only at its extremities, when the other needle was brought to it; but no consecutive points in the intermediate part. The north point of the needle being applied to the south pole of the magnet, the needle was rubbed from this point towards its middle, but was drawn over the magnet only $\frac{1}{4}$ of its whole length. When taken from the stone, the northern end remained northern, but torpid; the needle however going back exactly to the south. The northern point of the other needle when held near the northern point of this one, attracted it; but at a distance of $1\frac{1}{2}$ inches from this extremity a repelling force prevailed, and then again an attractive force extending to the south point; so that both extremities of the needle were attracted by the northern end of the other needle.

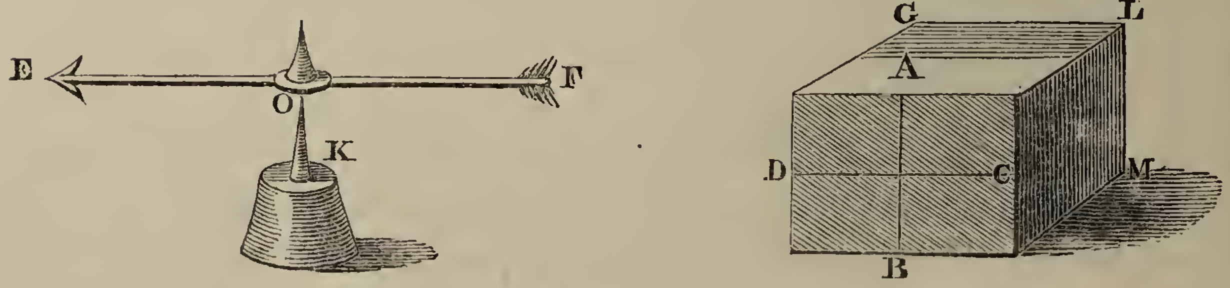
2. The friction of the needle was next extended from its northern extremity to its middle or centre, and was effected over the same pole of the magnet. In this case the needle, when placed upon a pin, turned round; having its south pole directed toward the north, and its north toward the south. Each extremity was attracted by the northern point of the other needle, when placed near it; at about 4 inches from one extremity, there existed an attraction; through a space of 4 inches from this, and therefore beyond the centre, there was a repulsion; from which spot an attractive force again extended to the opposite extremity. But when the southern pole of the needle under examination faced the northern cusp of the other, the southern repelled it, and the repulsion extended to a distance of 4 inches from the apex; from hence to the middle prevailed a state of indifference or one neither of attraction nor repulsion. From the middle extending toward the opposite apex there was an attraction for the length of 2 inches; and from hence to the extremity there prevailed again a repulsion. The learned Hamberger seems to have made a similar observation in his inaugural programme *On the Partiality of the Magnetic Needle;* and although his observations do not exactly agree with mine, yet I have no doubt they are true, and were skilfully made; for in these experiments there will be always some difference according to the time of the day, the season of the year, the length and structure of the iron, and the difference of the magnet which is used. "I drew," says he, "the upper surface of a needle over the north pole from the extremity towards the centre: the needle when placed upon a pin did not spontaneously direct itself to the north, though I observed in it some effort to do so, but in almost every position was quiescent." In our own experiment we always observed the needle to have a direction exactly in the line of the magnetic meridian, although it did not touch the magnet; however the centre O of the needle (Fig. 65, p. 39) had been cleaned from the scales produced by ignition, and which by their roughness deprive it of its mobility. He then proceeds: "When the north pole of the magnet was moved to the head of the needle, the latter receded; its tail however did not approach, but the entire needle, after several reciprocal vibrations, stood still so as to be perpendicular to a line drawn through the poles of the magnet to the centre of the needle; but when the south pole of the magnet was moved to the tail of the needle, the latter also approached to the pole of the magnet whose motion it followed. When the same pole was made to approach the head of the needle, the latter also approached to the pole of the magnet, and followed its motion; but with less celerity than the tail. The south pole of the magnet there-

fore was friendly to each extremity; but the needle in respect of the whole magnet was partial." In our own experiment each extremity of the needle was friendly to the north pole of the other needle ; an observation which is directly opposite to that of Hamberger. After the lapse of a month however I repeated the experiment, and the result agreed with the observations of Hamberger; for each extremity of the needle was in amity with the south pole of the other. So freakish is nature in her magnetic operations, as sometimes to produce opposite effects ; and thus in regard to the cause of her forces she makes a sport of the sagacity of mortals, and humbles the arrogance of their self-confidence. We may however easily understand the manner in which, in our first essay, both extremities of the needle were attracted by the same point of the other needle. For the southern extremity of the needle placed before us was attracted by the northern cusp of the other, before experiencing any contact with the magnet; and this force remained in the longest piece of iron, although the magnet was applied to the opposite extremity. Let us therefore conceive the northern extremity to be drawn some distance over the magnet, which therefore becomes southern, and that if it has sufficient power it would turn the needle, as it commonly does if the magnet be drawn farther over it. But the south pole is attracted by the north pole of the other needle ; in like manner the head of the needle, having acquired the force of a south pole, is attracted by the northern head of the other needle.

3. The needle was next drawn along its whole length, in the former direction, over the south pole of the magnet. This being done, it had the same direction as in art. 2, but it had no intermediate consecutive points ; its north head being attracted by the south pole of the other needle ; and its southern tail being attracted by the north pole of the other.

4. Finally, the tail of this needle which pointed to the south, was placed upon the north pole of the magnet, and drawn over it for the length of 2 inches. The direction of the needle remained as above ; but each extremity was repelled by the north pole of the other needle, and the intermediate part of the needle was attracted by this pole alone. A phenomenon which may be explained in the same manner as the first.

EXPERIMENT XCIV.


Figs. 67 *and* 68.*

---

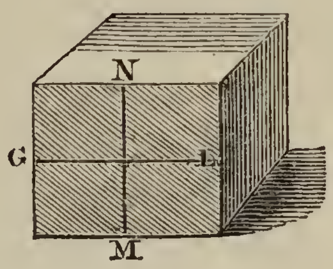
* In the original, plate XV., fig. 7 and 9.

Fig. 67 and 68. Let ADBC be the polar side of a magnet, and let EF be a needle moveable upon the pin K; let the head E be applied to the point in the magnet A,D,B, or C; let the needle be then drawn along its length EF from E to F in the direction AB, DC, BA, or CD, or in any other similar direction between these points. The head E of the needle placed upon the pin K will observe always the same direction toward the same quarter of the heaven.

2. Next let the tail F of the needle be applied to the same points of the magnet ADBC; and let the needle be rubbed against the magnet along the length FE from F to E in the direction from A to B, or D to C, as above; then will the head E of the needle, when again placed upon the pin K, be directed toward the same quarter of the heaven as in the preceding case.

3. Fig. 69. Let the same magnet be inverted so as to present to us a different pole GNLM. Let the head E of the needle be placed upon the points of the magnet G, N, L, or M, and let the whole needle be drawn from E to F over the pole in the direction GL, NM, LG, or MN. Then the head E of the needle placed upon the pin K will be directed toward the same quarter as in our second trial.

Fig. 69.[*]



4. But if the tail F of the needle be placed upon one of the same points of the magnet G, L, N, M; and if the whole needle be rubbed upon it from F to E in the directions GL, NM, LG, or MN, the head E will be directed toward the same quarter as in our first trial.

EXPERIMENT XCV.

Fig. 67 and 68, p. 44. If ADBC be the south pole of a magnet to which the head E of the needle is applied; and if the latter be rubbed from E to F, the head E of the needle placed upon the pin K will be directed toward the south quarter and the tail toward the north. But if the tail of the needle F be placed upon the south pole of the magnet and be rubbed from F to E, the head E will be directed toward the north quarter of the heavens. So that in order for the head E of the needle to look northward, it will be requisite always that the tail F be applied to the south pole of the magnet, and that the needle be drawn over this pole from the tail to the head.

---

[*] In the original, plate XV., fig. 8.

EXPERIMENT XCVI.

Fig. 70.*

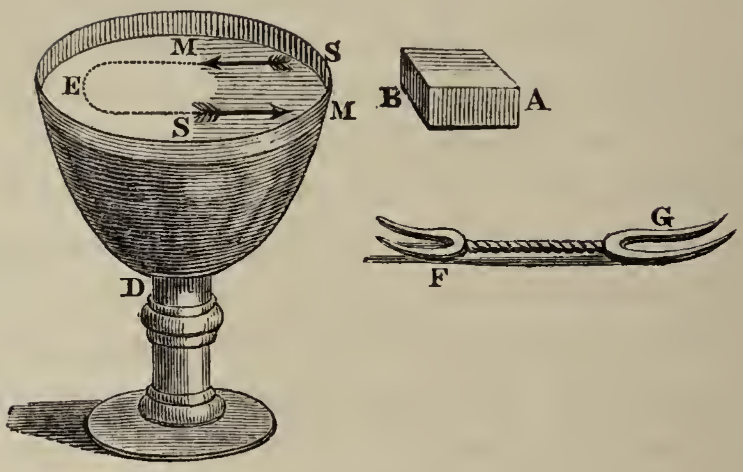


Fig. 70. Let D be a glass cup full of water, and let the mariner's needle MS impregnated with magnetic force, or a small new common needle, be placed by means of a small fork FG on the surface of the water so as to float upon it. Then let the north pole B of the magnet AB be turned to the needle, the southern point of which M will be attracted by this pole of the magnet. Let now the magnet be inverted, so as with the south pole A to face the same point in the cup; then will the needle MS also alter its position, describing the curve line SEM, and the tail S will face the pole A of the magnet.

This experiment described by Polinieri in *Experienc. Physiq.* p. 290, merits notice in consequence of the curve line SEM, which the needle describes upon the water; for it might seem as if it turned itself only upon the centre of gravity just as a mariner's needle rotates upon the pin; whereas it describes a curve similar to that formed by filings sprinkled round the magnet.

The other observations adduced by our author on the declination of the magnet we shall omit; and pass on to his fourth chapter, where he treats of the action of one piece of iron endowed with magnetic forces upon another piece, (see p. 235 of his work;) and then we shall proceed to experiment 110.

Since iron endowed with magnetic forces does not differ from a magnet itself, whether we regard its attractive power which it exercises upon other iron, or its directive power, or its power of communicating its virtue to other iron, we might waive the examination of iron, in so far as by attracting other iron it shews its magnetic virtue. Still we cannot treat the magnet in the various ways in which iron may be treated; for we cannot force the stone into any required form; we cannot twist one about the other, nor elongate it by drawing it through an aperture; nor change its shape by hammering, and subjecting it to the same inflections and mutations as a ductile metal. It remains therefore for us to examine the manner in which the magnetic virtue resides in iron; which is capable of being treated, and twisted about, in ways very different from any to which we have hitherto been able to subject the magnet.

---

* In the original, plate XII., fig. 4.

EXPERIMENT CX.

I see it is remarked by some philosophers, that the magnetic force decreases in a steel plate, if other thin and not large pieces of iron, which have never been drawn over the magnet, be rubbed against it; but that the force remains entire, if larger bodies are applied; of which too considerable a mass, scorning as it were the magnetic forces of the thinner lamina, withdraws nothing from them. But were this opinion true, still it would not affect what we have said on the magnet in our second chapter, containing experiment 38; namely, that the magnet never loses any degree of its forces, even though six hundred pieces of iron should be drawn over it in a short time; and this, whether they be thin and short, or thick and long. Hence I suspect that the experiment with the iron was not conducted with sufficient attention and caution; nor is my suspicion unconfirmed by facts. A steel plate 12 inches long, $\frac{3}{4}$ wide, and $\frac{1}{12}$ thick, drawn over the pole of a magnet, received an attractive force. I examined what weight of iron the plate carried from either extremity, so that I might know the magnitude of the forces. The weight being ascertained, twenty plates were brought into contact with and rubbed against the same extremity. These had never before scented a magnet; they were all equal and similar to the former. All these derived from the friction a magnetic force. I then tried what degree of weight the former plate now raised; whether its attractive forces had decreased after being communicated to twenty other plates; or whether they remained the same; and I found that they carried the same weight, and with the same facility as before; whence I concluded, that iron communicates indeed its forces to iron, but in such a manner as to exhibit only a profuseness of forces, without losing any of them by the communication. Whence then arises the error of those philosophers who maintain, that the forces of the iron are in this case diminished? We reply, from the following source. When several plates are drawn over the iron, the sordes are abraded which adhere to its extremity. Consequently, if to this extremity you attach any given weight to be carried, it is not attached immediately to the metal, but to interposed corpuscles; hence the weight which is thus separated from the iron by an interval, cannot be attracted with so great a force; as is evinced by the experiments adduced in our first and second chapters. This I affirm to be the true cause of the error; for on first making the experiment, I was inclined to think that the opinion of these philosophers was not repugnant to the truth; since I found that a plate carried less weight after being rubbed by the others, than before; but on observing the sordes attached to the extremity, and wiping it away, I found the plate capable of sustaining its former weight.

⁂

EXPERIMENT CXI.

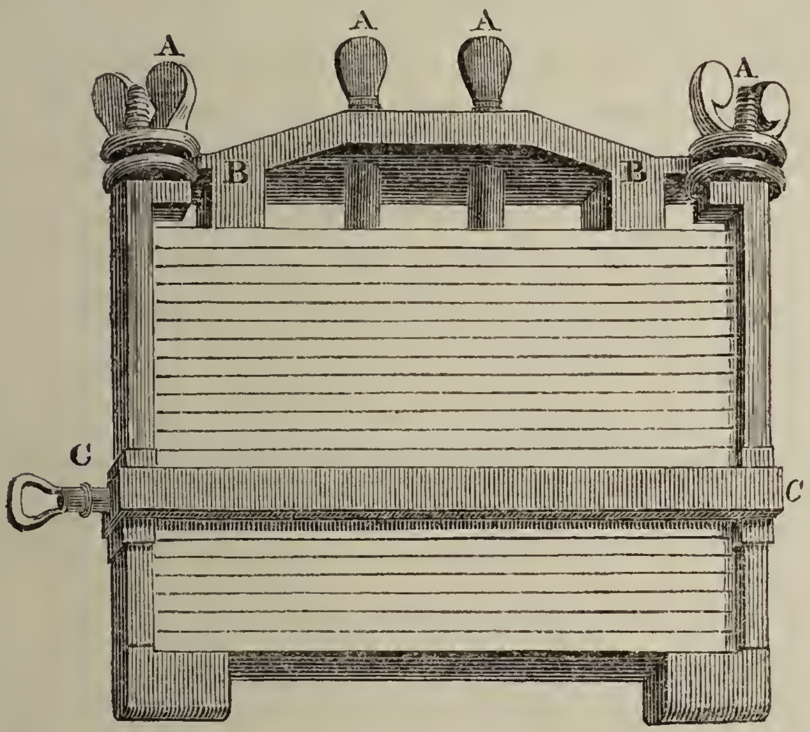
I next thought it desirable to ascertain the quantity of force received by the twenty plates rubbed over the first which had before been applied to the stone. In all these I found the attractive force to be nearly equal; but in each to be less than in the first plate. On one of the twenty I rubbed a large knife which was impregnated with magnetic force, but with less than that which was in the plate to which it was applied. On this knife I rubbed another, and again another, and on this again a fourth. The latter however received so little virtue as to attract scarcely a particle of filings, or of Virginian sand, such as it had before attracted. Had I been in possession of more steel plates equal one to the other, I would have continued to rub them in succession as before, and have noted the proportional decrement of the forces; but not possessing them, I was obliged, in extending the experiment, to make use of knives.

We thus see that iron communicates its force to iron, but in a less degree than itself possesses. Consequently the force communicated perpetually decreases in proportion to the greater number of iron bodies which are successively applied to it. It is therefore a property of the magnetic virtue, 1. To remain the same in quantity in iron; although the iron be touched with numerous other pieces of iron. 2. To generate or excite in a piece of iron of equal size a magnetic virtue less than its own. Consequently it cannot pass out of one piece of iron into another; because the same which before existed in the iron still remains.

EXPERIMENT CXII.

Inasmuch as iron and steel plates, when rubbed upon a magnet, are changed into true magnets; some philosophers have attempted, out of several plates disposed one upon the other, to form an artificial magnet which shall attract, elevate, and carry iron, as also communicate its force to other iron like a true magnet. This method of composing a magnet it may not be unacceptable to the reader, or useless for me, to record. A number of steel plates are chosen, well tempered, or hardened to the same degree of elasticity as sword blades. Throughout their entire length they are equally broad, thick, and highly polished. Their most convenient dimensions are 12 inches at least in length (longer ones are still better); $\frac{3}{4}$ inch wide, and $\frac{1}{12}$ inch thick. These, after being well impregnated with the forces of a liberal and good magnet, are placed one upon another in such an order, that the cognominal poles touch each other; and all accurately fitting form as it were one united body or parallelopipedon, which is represented in Fig. 71. To this body is applied an armature such as is used for the magnet, which, by a brass band furnished with a copper screw, is so tightened as closely to conjoin the extremities of the plates with the feet of the armature. The plates are also closely pressed together, so as to constitute one compact body; for which purpose there is attached at the top a copper beam BB, which, by aid of the four brass screws AAAA, is strongly forced down, thus uniting the plates into one solid mass.

Fig. 71.*



---

* In the original, plate XIII., fig. 2.

The greater the number of plates used in composing the magnet, the longer they are, and the more liberal the stone over which they have been drawn, the more powerful also will be the artificial magnet. For the plates are each respectively like a magnet, and the force of one assists the force of the other. Hence the number of plates being increased, the sum of the forces is increased; in like manner as when several magnets coagmented into one, have a greater power of attraction than only one or another taken separately. The quantity of attractive forces however at each foot of the armature, is not according to the number of plates, but is in a less ratio ; because the more distant the force is from the foot, the less it is ; as I have above demonstrated in the case of the larger magnets, the force of which is always proportionally less than in the smaller. We must here notice the observation of Hartsoeker, which he inserted in a paper entitled *Eclaircissemens des Conjectur. Physiq.*, p. 92. The attractive forces of each of the laminæ, which were of the same magnitude with those before described, he found to be 6 ounces. A magnet, composed of eighteen of these laminæ, elevated an iron weight of 6 or 7 pounds. After the lapse of six weeks, this magnet was the strongest and carried most weight. Each of the plates however, when examined separately, was very weak, sustaining only an ounce and a half or two ounces. These placed one upon the other carried only as much as they did before their dissolution ; while in the meantime both their poles possessed equal forces. Nor is there any doubt concerning this observation; because I found the case to be the same with my own artificial magnet. The magnetic force does not seem capable of being received by the armature of the plates so well in the beginning as after the lapse of some interval. Besides it is uniformly and constantly distributed throughout the united mass; so that both its poles are capable of carrying an equal weight.

EXPERIMENT CXIII.

Let a small piece of iron wire, extremely flexile and drawn over a magnet, be impregnated with its forces ; let it then be twisted into various forms and different angles ; and let the flexures be so forcible as to leave a mark of inflection or of roughening of the surface ; in this case nearly all the attractive force will be seen to be banished from the wire.

In these flexures the situation of the parts is changed; after the flexures other parts being brought into contact with each other different from the former. No portion of the substance perishes ; no accession to the iron is made; its pores are not clogged, but only a little changed; and yet the magnetic force before communicated is now destroyed. We have observed the same circumstance to occur in iron endowed with magnetic forces. When hammered it entirely lost them; and yet by these means it was only the situation of the parts of the metal that was changed. The cause of magnetism is therefore of such a nature, as to require throughout the whole of the iron the same situation of the parts which it had when it was drawn over the magnet; and it perishes or flies when any other disposition of the parts is anywhere induced upon the iron, or throughout the whole mass; nor can it revive except by rubbing against the magnet the iron thus bent. It is however surprizing that the force does not survive in that part of the iron which is not bent, and the parts of which retain the same situation as at first.

EXPERIMENT CXIV.

A piece of iron wire, or an oblong plane lamina, received considerable virtue from a magnet, by which at its extremities it raised an iron weight. It was next bent into the form of a ring, and both extremities touched each other. But immediately upon this, nearly all the magnetic force disappeared from the iron; nor at the juncture of the extremities could iron of any magnitude be appended; nay, the greatest part of the directive virtue was destroyed.

This has been observed by many of the learned; by Grimaldi, in his book on *Light and Color;* by De la Hire, in the *Philosophical Transactions,* No. 188, page 349; by Derham, in the *Philosophical Transactions,* No. 303. The latter, being exceedingly attentive to phenomena of this kind, has remarked, that all the directive force perishes if during the day-time the wire remain bent into the shape of a ring, and be afterward stretched out longitudinally; but that only a part of the force disappears, if the experiment be made in the evening. Nevertheless, the same extremities of the wire are attracted by the same pole of the magnet before and after the flexure.

To a person conducting this experiment it should be observed, that he ought to take care that the wire be not bent gently, or so that when left to itself it can recover its former rectilineal position; but that it be bent with a certain degree of impetus, so that the parts shall experience a violence, by means of which the wire may remain permanently bent. The result of the experiment is best seen, by convoluting the wire a few times round a cylinder in the form of a spire. In this case, after being drawn over the magnet, one extremity of the iron wire is a northern pole, another a southern. When the iron is bent so that each pole may touch the other, the force going out in an opposite direction and equilibrating it, the two necessarily destroy each other; so that another piece of iron cannot be attracted. For in the same degree in which it is attracted by one pole of the wire, it is repelled by the other; so that when acted upon by both together, the one action nullifies the other. But inasmuch as each pole is attractive, it ought to retain its force; nay, does retain it unchanged, if the wire be bent only so much as that it can spontaneously return to its former rectilinear position. It however loses a part of its virtue, if it is so bent that the situation of the parts is changed, and the surface roughened; as has been demonstrated above in experiment 113. We do not however as yet understand the nicety of the observation of Derham; for how does the morning or evening influence the magnetic forces, so that in the former case they shall survive and in the latter disappear? It cannot be the light that conduces to this result; for then the force would remain in the twisted wire in the day-time, rather than in the evening. Neither is heat or cold, by producing rarefaction or condensation, a cause; for winter days are colder than summer nights; and if it depended on cold, the force would always be found to survive in winter. All we can do then is simply to take note of this surprizing property of the magnetic virtue.

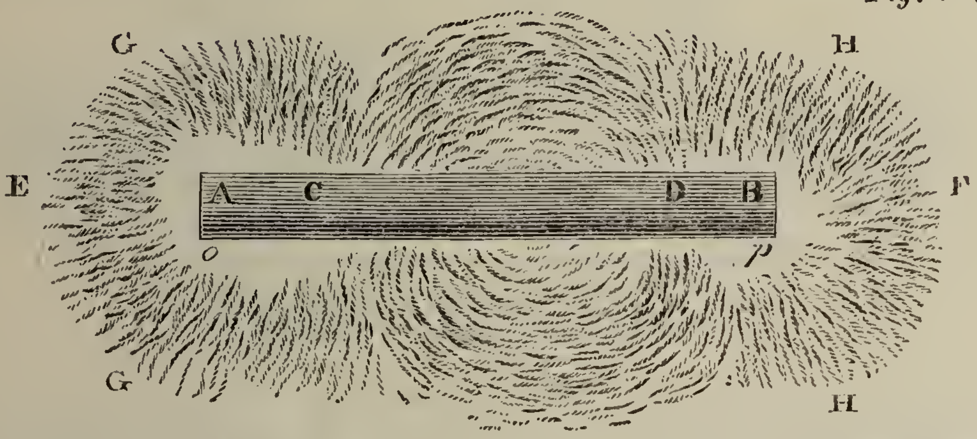
EXPERIMENT CXV.

If one extremity of iron wire, impregnated with magnetic force, be held firmly in a forceps, and the whole of the wire be twisted by holding the other extremity, so that the axis shall always remain the same or immoveable, and hence the internal situation of all the parts become changed; in this case, after the completion of the various intorsions, the directive force of the wire is observed to be considerably weakened, and sometimes inverted; so that the extremity which before was attracted by the north pole of the magnet, is now repelled by it. This experiment, if instituted with different wires, has been found to exhibit different phenomena; for before its intorsion the wire had no consecutive points; but afterwards it seemed to have been endowed with several, for when the needle was moved along the length of the wire, it was at one time attracted at the north end of its axis, and at another time repelled; as the very learned Derham has also observed.

EXPERIMENT CXVI.

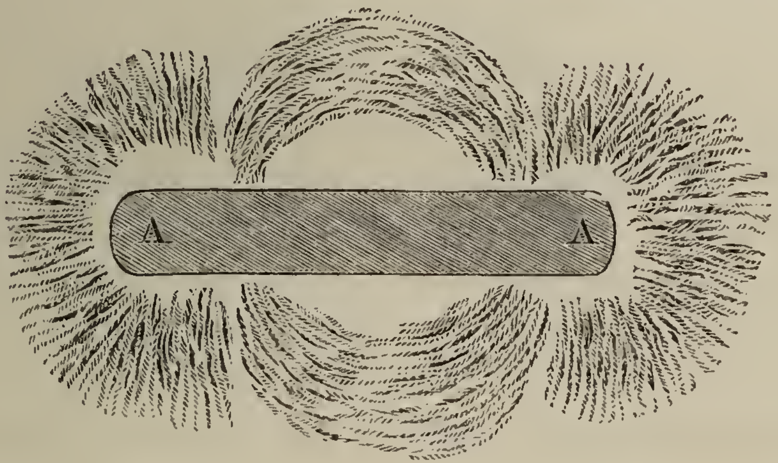
It will however be desirable to shew in what manner iron impregnated with magnetic force acts upon dust of iron, or upon Indian dust sprinkled around it. Let us commence with the most simple experiment (Fig. 72). ACDB is a steel plate 12 inches long. As described in experiment 122, after being drawn over a magnet, it was placed upon a plane glass speculum. The plate was of the form of a parallelopipedon, and around it was a sprinkling of iron dust or Indian sand; which was scattered thinly in order that the series might be the better perceived. The glass being then gently tapped, the powder arranged itself into series such as are represented in the figure. These were distant from each other by unequal intervals. Those which were in the region of the extremities A, B, lay in the same right line with the longitudinal axis of the lamina; as we see indicated by AE and BF. The series surrounding each extremity of the lamina A and B, at the distance of 1½ inches, that is to say, at C and D, lay also extended in right lines; although they surrounded the extremities, as is shewn in GG, HH. The middle part of the lamina CD was surrounded by iron dust arranged on both sides into curvilinear series; which do not appear to be the arcs of circles, but portions of other curves.

Fig. 72.*



When the angles of the lamina were so shaped that each extremity terminated in a round head, some Virginian sand which was sprinkled around it, was arranged into series similar to the former, as represented in Fig. 73; but when the extremities terminated each in a sharp point,

Fig. 73.†



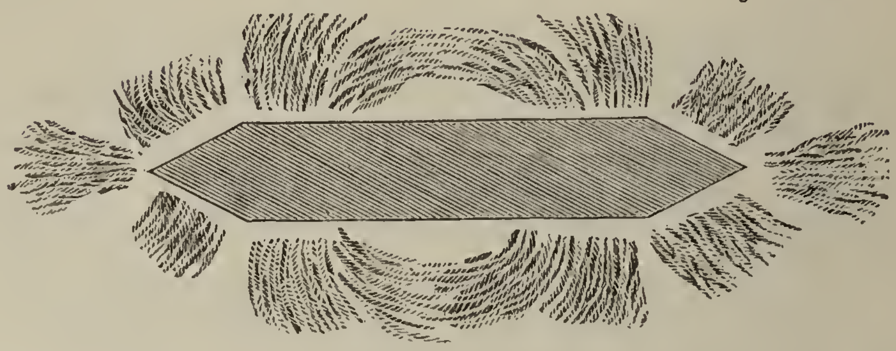
---

* In the original, plate XIII., fig. 3.

† In the original, plate XV., fig. 1.

the series were disposed in a slightly different manner, as is seen in Fig. 74. When the extremities however were bifid, as in Fig. 75, the

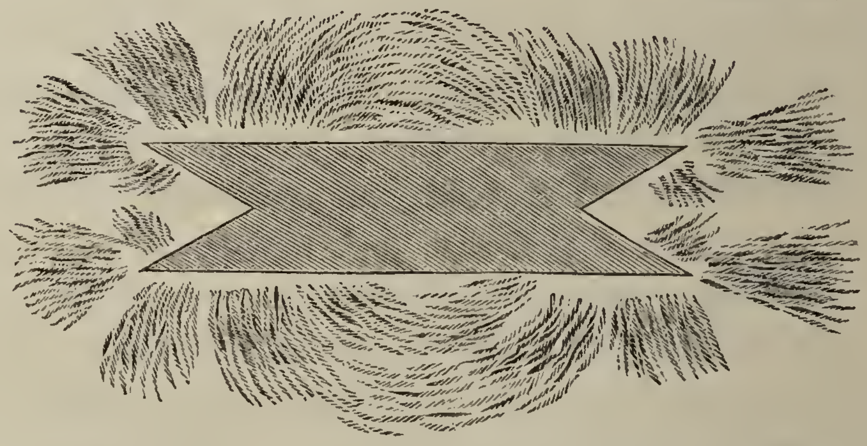
Fig. 74.*



series were arranged in a still different manner. For from every angle they radiated rectilineally as from the centre of a circle; in the interval between each point of the same side they inclined toward each other, but nevertheless did not touch each other. The middle of the lamina, as before, was surrounded by round series.

In the case of the square lamina exhibited in Fig. 72, we examined

Fig. 75.†



in what manner it attracted the dust upon which it was placed. To the thinner side *o*, *p*, adhered a large quantity; especially to the angles *o*, *p*, as also to the longest side between the angles *o*, *p*; and some portion, though a small one, to the plane superficies.

EXPERIMENT CXVII.

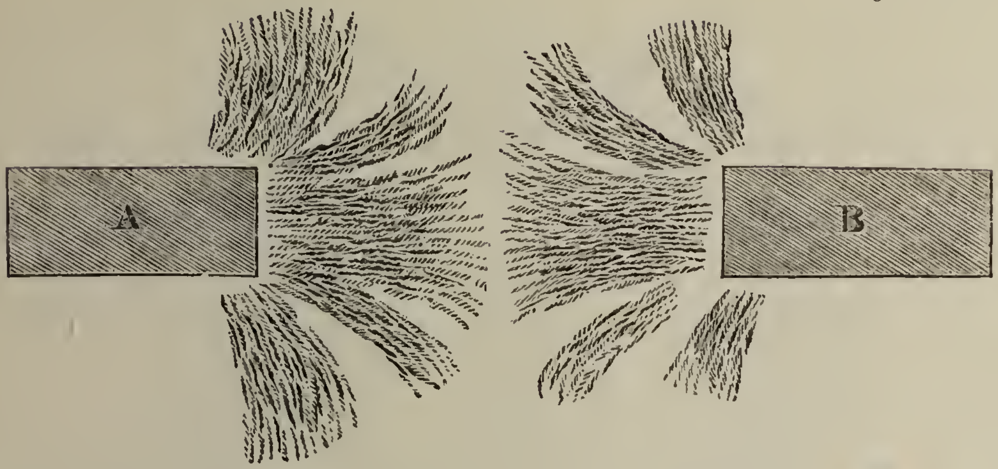
After this I placed upon a smooth surface or glass speculum two steel laminæ A, B, impregnated with magnetic force (Fig. 76); so that the two cognominal poles faced each other. In this case the Indian sand, which lay sprinkled about, was arranged into a rectilinear series proceeding from the polar surface. These became at the middle of the interval incurvated; mutually turning away from each other in such a manner, that no particle of sand in the sphere of the forces of the

---

* In the original, plate XV., fig. 2.

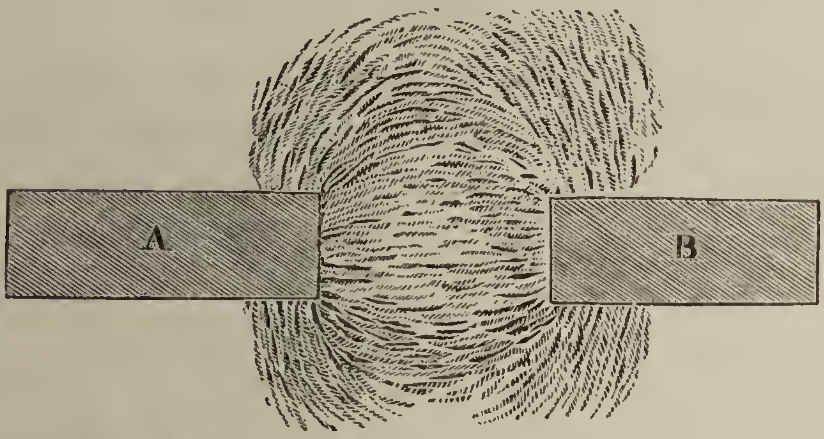
† In the original, plate XV., fig. 3.

Fig. 76.*



lamina A was attracted or adhered to the particles lying round the lamina B. But when either lamina was inverted, so that the two poles of opposite names lay facing each other, the Indian sand became arranged in a manner altogether different, as in Fig. 77; where the

Fig. 77.†



particles attracted each other and are seen to receive a certain direction from the forces of each lamina. In this case the series lay extended, in the middle of each interval, in a rectilinear direction; then on both sides they afterwards became incurvated in a greater or less degree, according as they were nearer to or farther from the middle; as will be seen from the figure better than by any description.

This order of the series does not differ from that occasioned by two magnets placed obversely to each other; for, when the cognominal poles face each other, the iron filings take the direction given in Fig. 76; but when the lamina and poles of alternate name face each other, the filings become arranged as in Fig. 77; which is not surprizing; inasmuch as iron drawn over the magnet, is impregnated with forces of the same kind, which in no respect differ from the magnetic.

EXPERIMENT CXVIII.

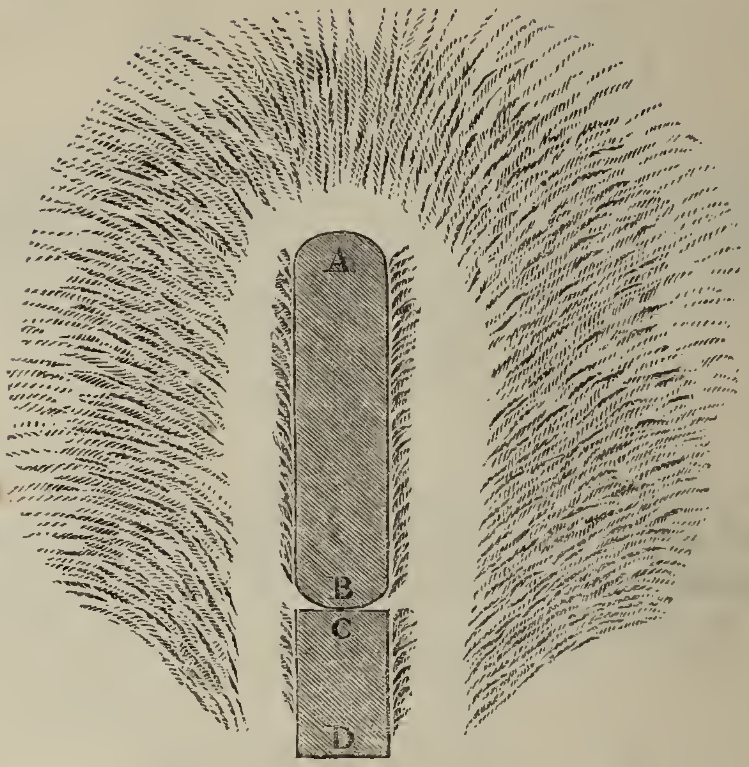
Fig. 78. Let AB, CD, be two steel laminæ joined to each other

---

* In the original, plate XV., fig. 4.

† In the original, plate XV., fig. 5.

Fig. 78.*



at B and C. Let the magnet be applied to their extremity, and let filings be sprinkled round the laminæ ; then will a small portion of them adhere to the sides ; another portion more remote will be arranged into series, extending anteriorly from the region A in a right line, but curved at the sides ; which will incline to the magnet the more according as they are the nearer to it. In *l'Hist. de l'Acad. Roy.*, 1717, De La Hire mentions a similar experiment conducted by himself. Let us compare this order of series with that which is represented in Fig. 73 (p. 53), and we shall observe a considerable difference ; entirely depending on the application of the magnet to the laminæ, or its withdrawal. In Fig. 78, its force passes in a right line along the length of the lamina ; from the sides of which it lies extended almost rectilinearly ; so that that curvilinear order evanesces, which otherwise would surround the middle of the lamina.

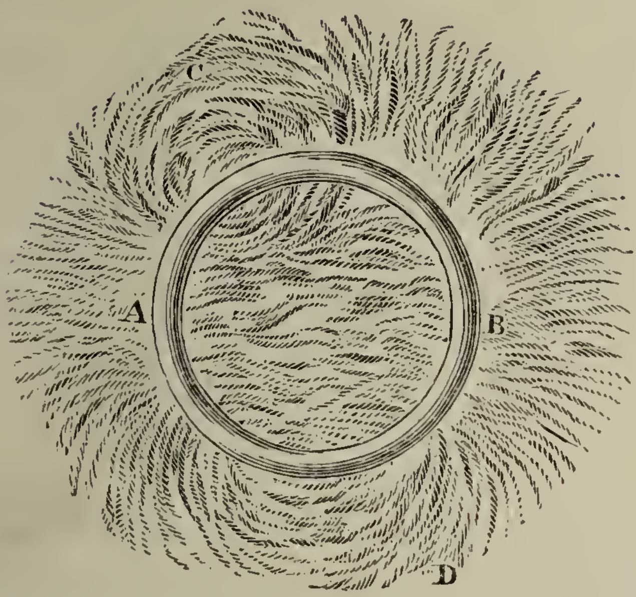
EXPERIMENT CXIX.

Fig. 79. Let AB be an entire ring of steel 2 inches in diameter. In conducting the experiment, the part A was drawn over the north pole of the magnet, and the part B over the south pole. Around the ring, which was placed upon a glass speculum, were sprinkled filings of iron or Indian sand. That part of the sand which lay near the rubbed places received the direction of a rectilinear series ; but at some distance from these places there were two curvilinear series formed as opposite to

---

* In the original, plate XV., fig. 6.

Fig. 79.*



each other as C, D. The sand, which was lightly sprinkled in the middle annular space, was arranged into curvilinear series from the region C and D; but for the most part was disposed in the same direction as the series near the rubbed places. The celebrated De La Hire first instituted this experiment which was described in the *Philosoph. Trans.*, n. 188; adding that he had rubbed upon a magnet a plate of iron terminated like a knife; and that the end, when turned to the ring, had attracted various parts, and not merely one only or the other only, such as A or B, as happened in the case of the mariner's needle; moreover that a steel ring rubbed upon a magnet had for some time retained its virtue, although the poles were placed contrariwise to the poles of the world. Also that a steel ring, rubbed against a most powerful magnet, receives with difficulty a contrary direction if it be drawn over a weaker magnet with an opposite determination; for although at the beginning it would seem to have lost its direction, yet in process of time its force and direction are recovered; just as happens in two magnets of unequal forces, the stronger of which, when their cognominal poles are applied one to the other, repels the directive force of the weaker and induces a contrary one; but when the two are again removed from each other they gradually recover their former state.

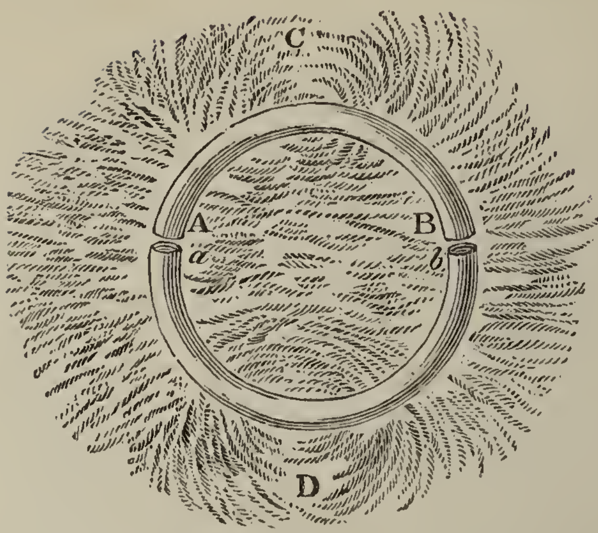
EXPERIMENT CXX.

Fig. 80. The extremities A*a* of two iron semicircles AB, *ab*, were rubbed upon the northern pole of a magnet, and the extremities B, *b*, upon the southern. Then around both, placed upon a glass plane at a little distance from each other, was sprinkled rather thinly Indian sand; which at the extremities A*a* and B*b* was arranged into

---

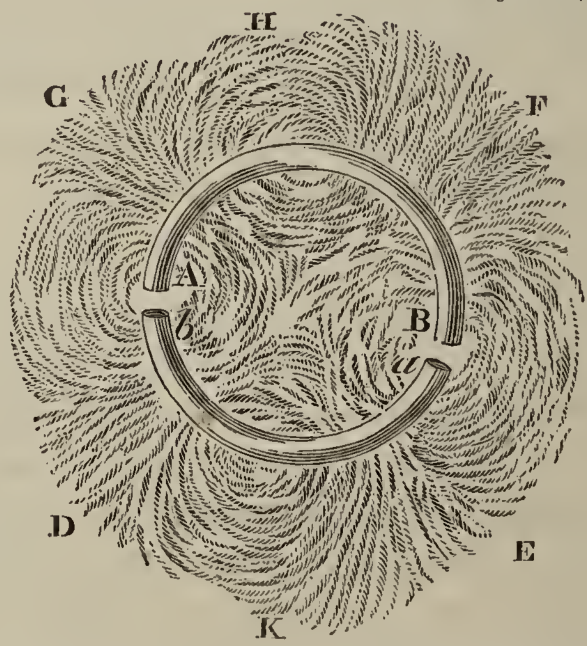
* In the original, plate XI., fig. 8.

Fig. 80.*



rectilinear series; while at the middle of each semicircle were formed curvilinear series at C and D. In the space intercepted by the circle, the sand was disposed into right lines, excepting a small portion which was in the region of the points C and D. The orders of the series were perfectly similar to those exhibited by Fig. 79 (p. 57), in the case of an integral ring; so that the former may be understood and explained from the latter. In Fig. 80 A and *a* are two cognominal poles mutually shunning each other; for both these extremities were drawn over the same pole of the magnet. Thus B*b* also are two cognominal poles mutually shunning each other; hence at the extremities there are in this case four poles. But inasmuch as these produce the same effects which we have noticed in the case of the entire ring (Fig. 79), in that case also there will be four poles, of which the two cognominal will adhere to A, and the two others to B. Hence the entire ring, in the two parts diametrically opposite to each other, when rubbed over both poles of the magnet, will be endowed with four poles; two in each of the parts attracted.

Fig. 81†.



---

* In the original, plate XI., fig. 6.

† In the original, plate XI, fig. 7.

If now either semicircle be turned, as in Fig. 81, so that the pole A faces the cognominal pole *b*, and the opposite pole B the cognominal pole *a*, but so that some interval shall exist between them, then around the extremities there will be formed curvilinear series surrounding A and *b*, as also B and *a*, to a considerable width. In the whole were seen four curvilinear series, and between these, four rectilinear series which De La Hire in the *Philosoph. Trans.*, n. 188, has likewise described as very beautifully arranged in the same manner.

EXPERIMENT CXXI.

The celebrated Derham instituted several experiments with pieces of iron wire; which, after being endowed with magnetic forces, were cleft longitudinally; in which cases he observed the following phenomena. 1. The poles were frequently inverted, so that the north became the south; in like manner as if the wire had been drawn afresh over the magnet in a direction opposite to the former. 2. Sometimes one half of the wire preserved the same magnetic force, while the direction of the other half was plainly inverted. 3. Sometimes no change was induced upon the magnetic virtue, with the exception merely of a decrease which takes place in all wires upon being cleft. 4. When one part of the wire experienced after cleavage a change of direction, this part was always the thinner; the thicker remaining the same. 5. Sometimes after cleavage the pole of one part of the wire had been changed, while the other extremity remained indifferent, or was allured by the northern pole of the magnet and by the south equally. 6. Sometimes one part of the wire was attracted by one pole, but the same extremity was neither attracted nor repelled by the other pole of the magnet; as if it knew not whither to turn. The learned Derham suspected at first that the change of direction arose from the violence experienced by the wire in cleavage and flexion; but this opinion he afterwards rejected, observing that in the case of some wires that were cleft and but little inflected, one half had experienced a change while the other part remained the same; also that the direction remained the same in the case of some wires that had been exceedingly bent. Besides he observed that it was the same thing whether the cleavage was begun from the north pole or from the south.

EXPERIMENT CXXII.

Inasmuch as iron wire by cleavage acquires one surface that is flat, namely, the part traversed by the wedge; and another surface that is gibbous; there is a considerable difference in the direction, according as the wire is placed upon a plane, and its flat surface made to face upwards or downwards. If the gibbous surface be uppermost, while the flat one lies horizontally underneath, then the wire will be attracted by the two poles of the magnet, and will be also repelled by them. If the wire be inverted, so that the flat surface looks upwards, then one extremity will be attracted by one pole of the magnet and repelled by the other. This has been closely observed by Derham, who thought that the change of the direction depended upon the conversion of the poles produced by the cleavage, which caused the north pole to become south; but he was never able to discover that the sides of each extremity or of the other part, were the same, on opposing the magnet either to one side or the other.

EXPERIMENT CXXIII.

Let a lamina of steel 12 inches long, such as is used in making an artificial magnet, be impregnated with the magnetic force; then let a fresh iron rod or lamina not very thick be placed on a blacksmith's anvil; and it will be found, that when the extremity of the first lamina is brought into apposition with this rod, the latter will indicate a great attraction, by cohering strongly with the lamina. But if the rod be placed upon wood, upon stone, upon the hand, or upon any other body not iron, then its attraction by the first lamina will be two or three times less. The larger the anvil on which the rod is placed, the greater will be the force with which the rod is attracted by the lamina, and to the greater height from the anvil is it capable of being raised.

For this observation we are indebted to Reaumur, in *l' Hist. de l' Acad. Roy.*, 1723; in which we observe the same effect produced by a large anvil which is produced by the magnet. Two keys, applied to each other over a magnet at a considerable distance from it, cohered with a force issuing out of the stone. The same force issues out of the anvil that excites attraction in two laminæ placed in apposition with each other, or that increases it when excited, which is the same thing. In the same manner as keys, held at some distance over a magnet, became attracted to each other with a less force than when held lower down, so that one fell from the other; so also the rod adhering to a lamina held at a distance above an anvil falls down separated from it; provided the lamina be made to recede from the anvil; another proof that iron is a magnet, and differs from it only in this, that it is possessed of a less degree of force, unless it shall previously have been made to touch a magnet.

EXPERIMENT CXXIV.

I next twisted round each other two iron wires, just as ropemakers twist two ropes in making a larger. The length of the wires was 4 inches; the diameter $\frac{1}{12}$ of an inch. This I drew over the south pole of a magnet. With each extremity they repelled both the north and south pole of the needle; while with the middle part they attracted each pole. These wires were then bent, so that the cognominal poles touched each other. Both extremities possessed a bifid head, each of which attracted the north pole of the needle and repelled the other. The two opposite heads attracted both the south pole and the north; while the whole of the intermediate substance of the wires repelled the north pole, and kept the south motionless and in suspense. 2. Two other wires of the same length were mutually twisted around each other; both of which had attracted with one extremity the north pole, and with the other the south, and again had reciprocally repelled it as good mariner's needles do. These wires were twisted into one; and terminating with a bifid head, with one extremity they attracted the north pole of the needle; with the other they repelled it; but with each extremity they repelled the south pole of the needle. With the intermediate portion of their length, when opposed to the northern cusp of the needle, they kept it motionless, neither attracting nor repelling it. They attracted however the southern point. This experiment is of such a nature as not to be easily understood, however clearly described, unless a person undertakes to repeat and try it in different ways.

EXPERIMENT CXXV.

Some iron wire, which was drawn over the magnet and was 4 inches long, with one extremity repelled each pole of the needle; with the other attracted the north pole, and repelled the south. The extremity which had repelled both poles, being hammered upon a stone and flattened, repelled, though but feebly, the north pole of the needle, and attracted the south. The other extremity of the wire, which also was flattened by hammering, attracted the north pole, and repelled, though but feebly, the south. The intermediate portion of the wire was endowed with two consecutive points; one of which repelled and the other attracted the northern cusp of the needle. 2. When this wire had been drawn over the south pole of the magnet, one extremity was observed to attract the north pole of the needle, and the other the south pole. When the middle was struck with a hammer and flattened to the length of 1 inch, the directive force at each extremity remained the same, but much enfeebled; nor did the intermediate length seem to be endowed with any consecutive points.

EXPERIMENT CXXVI.

I examined two pieces of iron wire 4 inches long, which had been rubbed against a magnet. With one extremity they attracted the north pole of the needle, and with the other the south. The cognominal poles of the wires were placed upon each other to the length of half an inch; and after receiving some blows of the hammer upon a stone anvil, on which they became mutually flattened, the flattened extremity of one wire, when opposed to the northern cusp of the needle which it had before repelled, now attracted it; while the same extremity of the other wire repelled the north pole of the needle as before.

EXPERIMENT CXXVII.

Inasmuch as from our preceding experiments we might be induced to think, that the changed situation of the parts which compose the mass of iron, must originate a difference in the magnetic direction; I would observe, that before adopting this opinion, I deemed it advisable to undertake other experiments in which the situation of the parts is changed, but changed in a manner somewhat different from the former. A piece of iron wire, which was 4 inches long and of the same thickness with the foregoing, was drawn over the pole of a magnet; and with one extremity attracted the northern point of the needle, with the other the southern; nor in any intermediate part did it present any symptoms of consecutive points. The wire was now drawn through a very narrow foramen made in a steel plate, and by these means acquired a length of 5½ inches; the poles at each extremity remaining the same and exhibiting remarkable powers; but again no consecutive points were observable throughout the entire length. When the same wire was afterwards passed through a narrower foramen, by means of which it became 7 inches long, the same direction remained as before; one extremity attracting the north pole of the needle and repelling the south, and the other extremity attracting the south pole and repelling the north ; nor did any further attenuation of the wire, by passing it through a narrower foramen, superinduce any new direction, or change the former one. Still in these experiments the situation of the parts of the wire was changed, and in such a manner that probably there were none which before had touched each other which now adhered or remained contiguous to each other, but were removed to a considerable distance.

The changed situation of the parts therefore cannot be called the universal cause of the inverted direction ; for there are some cases in which the iron has a different direction when its form is changed, and other cases in which no difference of direction is observable. To any one who in future may be so fortunate as to discover the cause of the magnetic virtue, these phenomena will become intelligible ; although such as are mentioned in the present chapter are not the easiest to be understood. While we are ignorant of the cause of magnetism, we are only like moles burrowing under the earth. We go in search, we investigate, we move onwards in labyrinthine directions, sometimes meeting with soil altogether barren, sometimes with such as slightly rewards our labours. Let this however serve as our solace under every vicissitude; that an experiment rightly instituted and accurately observed under all circumstances, remains always an experiment; that is to say, always true, and always in some degree useful, nor ever liable to those alternations which overtake even the most subtle arguments originated from a slender hypothesis.

EXPERIMENT CXXVIII.

Let a piece of iron which is not impregnated with any magnetic virtue, except such as it acquires spontaneously, be held near either extremity of a needle ; it will then change the direction of the needle, and attract it to itself just like a genuine magnet. The needle moreover will follow its motion, and be made to describe a circle or be made to stop at different points and be directed at will by only moving the iron. If however the latter be endowed with a magnetic force, it will attract the needle at the same distance as before much more strongly ; or if placed farther off, will nevertheless give indications of its influence.

CHAPTER XII.

ON THE OPERATION OF IRON AND OF THE MAGNET UPON THE MARINER'S NEEDLE; AND ON THE RECIPROCAL OPERATION OF ONE NEEDLE UPON ANOTHER.

A PRIORI OR FROM FIRST PRINCIPLES.

The sphere of the effluvia around iron extends itself to a considerable distance; so that the vorticles or gyrations of effluvia emit themselves like radii on every side, and dispose the magnetic element itself into the same situation; whence the magnetic element regards the iron as its pole or centre from which the vorticles issue in a long series. Not only does a tide of effluvia perpetually emanate from the iron, but it also constipates and surrounds its surface; a circumstance so evident, and from so many phenomena arising from the conjunction of the magnet with magnetic needles, as to be placed beyond a doubt. We see the magnet assuming to itself forces from the iron: we see the iron reacting upon the magnet in like manner as the magnet acts upon the iron: we see the needles themselves turning toward the iron as toward their pole, incessantly facing it and regarding it as a centre; and this not only at a distance of digits but also of even feet and ells. And inasmuch as, according to the theory propounded in our preceding chapters, there is no difference between the magnet and iron, with the exception that iron is not encompassed with a regular connected and contiguous sphere extending from one pole to the other, we may learn hence the nature of the sphere which surrounds the iron. The situation of the smallest parts within the iron is irregular; as also at its confines or surface. But inasmuch as there are effluvia which occupy the surface, and conjoin themselves with those which are within the iron, it follows that the iron is surrounded with a sphere which is colligated to the body itself. That this sphere however is not regular and connected, we have already shewn. If it be not regular and yet be colligated to the iron body, it must be thus colligated from all parts of the body; whence the sphere around the iron constitutes a certain species of contiguity. If it be thus colligated, it can be only so that the gyrations or vorticles may connect themselves according to their spires; if according to their spires, this kind of connexion will extend from the iron to some distance from it; and if so, then all round the iron in like manner. For the vorticles cannot be colligated otherwise than conformably to the course and mechanism of their spires; that is to say, so as in general to form right lines proceeding from the iron in every direction. And thus the vorticles of effluvia extend themselves as radii to all parts around, according to the mechanism of their conjunction. But inasmuch as the whole of this sphere has no figure; inasmuch as it does not connect itself by continuous flexures from one pole to another; nor thus maintain a given relation to an axis, nor on each side the axis to its magnet, nor thus the magnet to its sphere; it follows that, in the sphere belonging to the iron, there cannot inhere any magnetic force; but that on the approach of another sphere, such as the magnetic, it immediately yields; since of itself it cannot conjoin anything with itself, nor repel or avoid it; because there is no connection of parts, no cohering and continuous concatenation from one pole to another.

Such as is the situation of the vorticles, or the figure of the sphere, such is the situation, or figure of situation, of the elementary particles vortically moved. In the fore-mentioned element the gyrations are performed conformably to the axes and equators of the particles; for they begin in the centre, and spread themselves around after the manner of a spire; and terminate themselves conformably to the situation of the parts. If the vorticles conjoin themselves as to their spires, then do they conjoin themselves altogether according to their motion, and the motion applies itself to the situation of the particles. Therefore such as is the situation of the gyrations or spires, such also is the situation of the elementary particles, which must necessarily adapt themselves to the motion. Hence arises the general rule, that such as is the situation of the elementary particles, such is also that of the vorticles; that the motion of the vorticles converts the elementary particles into the same situation with its own; and that the situation of the elementary particles is such as is the figure of the sphere, whether around the magnet or around the iron. Therefore the elementary particles, with their axes and poles, so dispose themselves in every direction from each piece of iron, that they regard the iron as their centre; and that their axes are radii and diameters, according to which the spires and helices of all the vorticles are conjointly enabled to embrace themselves at a distance from the centre. On these subjects however we have already treated.

2. *Innumerable other spheres, whether pertaining to iron or to a magnet, may be formed within one and the same sphere; and each sphere may operate according to the situation and motion of its parts.* Just as is the case in other elements on a larger scale; as for instance in the air, where a thousand sounds and modulations may spread from different centres either simultaneously or successively; in water, where a thousand undulations may spread one beyond and over another, and all within a larger one; especially too in the ether, where there may be almost infinite centres and infinite modifications, one presenting no impediment to the other. An element which is in motion as to its volume, is not displaced, in respect to its particles, from its natural situation; neither is it deprived of equilibrium. In their motion the particles observe the same reciprocal relation as in a state of rest. For local motion and translation are not of individual parts, but of the volume. In this motion the particles are not to be considered as otherwise than in a state of rest; because, in respect to the neighboring particles, they continue in their natural situation. Hence by reason of the motion among the particles there is no loss of equilibrium. Therefore it is of no consequence if a new motion exist within the sphere of the other, and again another motion within the sphere of this. Nevertheless the particles have naturally a reciprocal relation to each other; for a common motion is as rest, relatively to the

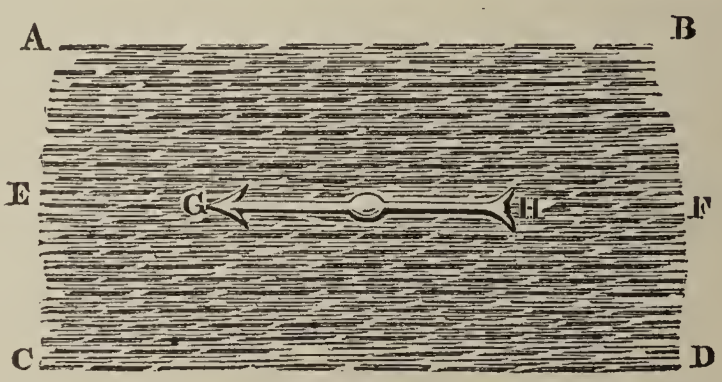
individual parts. Innumerable spheres therefore, whether pertaining to the magnet or to iron, may exist within a single larger sphere.

3. *In every magnet there are qualities and forces of two kinds; one, that of conjoining with itself another magnet or piece of iron, which is called the attractive force; the other, that of accommodating itself to the parallelism of the magnetic element, or to its poles, which is called the polar force or declination of the magnet.* With regard to the first, it arises, as we have often shewn, from the reciprocal complexure of the gyrations, and the mutual application of magnets and pieces of iron; with regard to the second, it arises, without the application of any magnet, solely from the elementary contiguous medium. For the magnet, when left freely to itself, as also the needle when rubbed upon a magnet, directs itself into its polar position as it were spontaneously; that is to say, into the parallelism of the parts of the element.

4. *Within the sphere of the iron, at any distance from it, the mariner's needle becomes turned toward the iron, not by an attractive force, but by its own polar quality.* We say, not by an attractive or conjunctive force, because there is no ligation of vorticles or spires beyond an obliquity of forty-five degrees; and the gyrations or spires at a distance are of too obtuse an angle to allow of mutual ligation. But inasmuch as the arrangement of the elementary particles around all iron is diametral, or is radiant from a centre, the sphere surrounding the needle naturally disposes itself into accordance with the position and parallelism of such particles; because it is formed on mechanical principles; so that the needle turns itself by reason of its own polar quality, and not by reason of any attractive force. For even were no iron present, it would immediately turn itself, conformably to the parallelism of the magnetic element, toward the poles of the world. But in the present case, inasmuch as the situation of the same element around the iron is relative not to the pole of the world but to the iron, as above stated, it follows that the needle with its sphere seeks its equilibrium in this situation, and aims at a state of rest upon mechanical principles. According to our twenty-third thesis in the first Chapter of this Part, it is evident, that *the axis of the sphere, or the common axis of the vorticles, lies the most conveniently in a parallel posi-*

tion with the common axis of the element itself; but that nevertheless it may be easily converted thence in a direction toward any other quarter. If it be made to have respect to the iron, then it lies the most conveniently in a parallel situation; because the elementary parts which are at a distance according to the size of the sphere, observe a relation to the iron such as we see in Fig. 82, where the needle lies in a position according with the current and situation of the parts. But inasmuch as the needle is surrounded with a sphere of the same parts, it can do no other than convert itself into an accordance with the common situation of those parts.

Fig. 82.*



5. How astonishing and manifold are the *lusus naturæ* presented to view by the mariner's needle on applying the magnet to it in different ways! At one time we see it shunning its pursuer, dreading and recoiling from its presence and contact; at another, spontaneously hastening, nay, rushing, to meet or embrace it. At one time obliquely stationing itself by its side, and eyeing the magnet as it were askance; at another, somewhat elevating its position and looking down upon it as with supercilious glance; at another, lying along its side submissively and watching the magnet laterally with attentive eye; at another, flying away and sallying in a circle to the other side of the magnet, either to meet it or become its companion; and then again it is seen oscillating and quivering its head, and amusing the spectator with different fantastic and sportive vagaries according to the different motions of the magnet. And inasmuch as the eye is enabled to see nothing beside the magnet and the needle, both of which are hard and iron substances, separated from each other perhaps by partitions of brass, one

---

* In the original, plate XVIII., fig. 2.

might almost imagine the intervention of some spirit or genius to be the cause of such extraordinary movements. But as all these motions arise simply from the application of spheres, effected when the poles are either hostile or amicable to each other, when the equators, or the sides between the poles and equators, are applied above or below; and as it would be tedious moreover to represent these varieties by figures, especially since the results have already been explained in Chapters I. II. III. IV. V. of the present Part; and as all possible modes and varieties may likewise be explained by the same causes and first principles, it will be sufficient for the explication of these wonders to refer the reader to the several chapters already enumerated.

A POSTERIORI OR FROM EXPERIMENTS.

EXPERIMENT CXXIX.

It yet remains for us to examine in what manner two needles, endowed with magnetic force and placed in the same horizontal plane within the sphere of each other's action, operate one upon the other. One needle employed in this experiment was 6¾ inches long; another 9 inches ditto. Each was placed upon its pin, upon which it could turn freely. One was parallel to the other. Each with its northern cusp faced the north. The centres of each, or the pins, lay in a right line parallel to the magnetic equator; in which they were placed at pleasure, either nearer one to another, or farther off, in proportion as the needles approached each other. The shorter needle was placed eastward of the longer. Then first, when the pins were at a distance from each other of 4 inches, both the northern poles slightly approached each other; and the southern poles as much receded. When the pins were placed still nearer, so as to be distant one from the other only 3 inches, then the northern poles slightly receded from each other, and the southern poles slightly approached. The same results were observable when the pins were distant from each other 2½, 2, 1½ inches. But when they were brought still nearer, the needles turned round, and embraced each other with their cusps of alternate name.

2. The same phenomena were observable when the shorter needle was placed eastward of the longer.*

3. When the longest needle was placed in the magnetic meridian,

---

* Query.—*(Tr.)*

the other was brought to it, but in the same meridian. In this case the direction of each remained in the same meridian; the north pole of the one facing the south pole of the other. And this continued to obtain at every distance of the centres one from the other; provided they did not touch one another.

4. When both observed the same meridian, one was turned round with the finger, and its northern cusp held steadily to the west; in which case the northern cusp of the other also became spontaneously directed to the west; still it deviated from an exactly western direction by a greater or less number of degrees, according as the centres were nearer to each other or farther apart.

EXPERIMENT CXXX.

Finally two needles were placed over each other, so that the pins of both were in the same right line perpendicular to the horizon, and consequently both needles in different planes. Various experiments with these needles were formerly made by De La Hire, who inserted them in *l'Hist. de l'Acad. Roy.*, A.D. 1692; and as these were properly conducted and are well described, we shall furnish extracts from the author's own account.

1. He took a capsule which belonged to a compass, and which was furnished with a copper circle divided into 360 degrees; from the middle of which projected a pin on which was placed a needle, freely moveable, and 3½ inches long. He turned the capsule until the needle pointed to 360 degrees. The capsule was then closed in with a plate of glass; and he took another magnetic needle of the same length as the former, which he placed only upon the glass plate; so that its cusp pointed to the north, or was directly over the cusp of the needle in the capsule, the one being longitudinally parallel to the other. The needle upon the glass lay motionless; but the cusp or head of the needle in the capsule turned round toward the west, and after some vibrations remained motionless at 42 degrees westward.

2. The needle in the capsule veering at first, relatively to the needle placed over it, a little to the east, the northern cusp of the needle in the capsule continued to take a direction to the east, and after some vibrations stood immoveable at 41 degrees eastward; thus declining from its first situation toward the east, as much as in the preceding experiment it had toward the west.

3. After this, the uppermost needle being removed, the needle in the capsule returned to 360 degrees. Then again the other needle was

laid on the glass in such a manner that its northern cusp looked to the west, and both needles thus cut each other at right angles. In this case the northern cusp of the needle in the capsule turned eastward 13 degrees.

4. The uppermost needle being again removed, and the other in the capsule remaining quiescent, the former was laid upon the glass with its northern cusp looking to the east. In this case the northern cusp of the needle in the capsule moved eastward 13 degrees.

5. As the northern cusp of the needle in the capsule, in our fourth experiment, was distant from the southern cusp of the superior needle above it 77 degrees, so now the southern cusp of the latter was brought nearer to the northern cusp of the former by 10 degrees; in which case the northern cusp approached the latter by 5 degrees.

6. When the needle laid upon the glass was made with its southern cusp to approach by 5 degrees to the northern cusp of the needle in the capsule, then suddenly the northern cusp of the one approached the southern cusp of the other; so that both needles lay as it were immediately one above the other; nay, the cusp of the needle in the capsule elevated itself so as to touch the glass in the part immediately under the upper needle.

7. It now remained for experiments to be made with two needles, both of which should be moveable upon a pin. These were so placed that the pins lay in one continued right line, that is, one directly over the other, and at a distance from each other of 10 lines. In this case both cusps of the needles were directed northwards, not in such a way that the needles were parallel to each other, but that one deviated from the north toward the east, as much as the other deviated from it toward the west.

8. The needles were then placed upon pins, with shorter axes so as to be nearer to each other than in the preceding experiment, and to be mutually distant only $\frac{1}{3}$ of an inch. When both northern cusps were directed northward and left to themselves, then they spontaneously separated from each other to a distance of 46 degrees; and when one veered to the east the other veered to the west.

9. When the southern cusp of one needle was placed over the northern cusp of the other, then both embraced each other and remained in the same place; whence they had no true direction northward or southward.

10. When both the needles were rapidly turned round and then left to themselves, they did not become quiescent till the northern cusp of one needle embraced the southern cusp of the other.

CHAPTER XIII.

ON OTHER METHODS OF MAKING IRON MAGNETICAL.

A PRIORI OR FROM FIRST PRINCIPLES.

Iron may be rendered magnetical by other modes besides friction and contact. The art and method of effecting it, consists only in reducing the smallest parts which can exhale in the form of effluvia, into a regular situation. By the friction of the magnet with the iron all the smaller parts or elements of the effluvia are brought into a regular position; for they conform themselves to the course and tract of the magnet, and follow in the direction in which the magnet precedes, and which it thus points out. The greatness of the force of attraction acquired by the iron, is sufficiently evident from experience. For if the magnet be generous, the iron will be capable of supporting spicula, and even large ship nails; it will collect together the ramenta and filings of iron into the form of light straw, and draw them after it with a tenacious hold, if it be not too quickly moved. These we may see suspended around the poles like a head of hair, or a beard; for one particle hangs in a state of connection with the other, forming in appearance a fence composed of so many bristles or pikes; and hence with still more facility does the force of attraction govern the congeries of the smallest parts of the iron. By mutual contact and approximation, therefore, it disposes at pleasure the tide of the minute parts in the iron which exhale in the form of effluvia. Mutual contact is consequently the first and principal mode by which iron is endowed and imbued with magnetic virtue.

But since it is evident that the cause of the magnetic virtue consists solely in the regular and parallel situation of parts, we may ascertain whether there can exist other modes by which the same effect can be obtained. We know that the magnetic element flows always with a rectilinear, parallel, or perfectly regular position; and has a continual relation to its poles. We know that this magnetic element is exceedingly subtile, and penetrates the smallest pores of bodies; especially if in the course of formation these pores have already been penetrated by the element. *If therefore iron be exposed to the continual action of the magnetic element for a considerable and stated period, it will be rendered magnetical; particularly if it be laid in a position accordant with the parallelism of the elementary particles.* For from experience we may learn what is the declination, and what the inclination of the magnet. If iron therefore be so placed as to decline and also to incline at the same angle, then is there reason to hope that it will the sooner be imbued with the magnetic virtue, and will derive from its element its nature and character, and be rendered pervious in a parallel or rectilinear direction from one extremity to the other. Just as when a mineral in the earth and in its matrix is born magnetical, or imbibes a conjunctive and polar force. For it lies there for a considerable time undisturbed; always exposed to the element which thus permeates its pores, and which regularly disposes the smaller parts into conformity to its own ordinate arrangement, filling them with all its own force, and as it were fixing it in the stone.

Perhaps also the minutest parts are capable of receiving a regular ordination, by exposing the iron after ignition to an extremely slow process of frigefaction; though some skill is required in effecting this object, and enabling it to acquire hardness by distinct gradations and stages. When the iron is ignited, the state of its parts is extremely unsettled; particularly of those which are the least able to resist the action of the fire; for there are some which, like wax or sulphur, soften and liquefy with a very small degree of heat, and which with a high degree are rendered exsilient like hot water; there are some which yield only to the strongest degree of heat; some which yield indeed to heat, but are driven about from place to place with parts which are free; there are others which remain immoveable, and seem to disregard every degree of incandescence. Nor are the motion, turmoil, and contention of the parts the less considerable during the process of cooling; for the fire hastens and as it were pants for contact with the cold and humid atmosphere, escaping at any outlet it can. Whatever opposes its passage it dislodges and disperses, and if there is any difficulty in finding a vent, it lacerates, decomposes, abscinds, and tears asunder the obstacle, not suffering itself to be pent in by the pressure of surrounding particles; for those parts which are liquid and less rapidly cool, it does not abandon at the same moment as the more stubborn and more quickly coalescing. Thus during the process of cooling, the iron does not dispose itself, as to its interiors, into magnetic order. Unless therefore it concretes or hardens very slowly, and unless its state while cooling be allowed to become tranquil by the slowness of the process, the adoption of any method of producing magnetism will be unsuccessful.

2. *Iron may be rendered magnetical likewise by repeatedly stretching and bending it; as also by a regular rasping, and by hammering it out.* For tenacious and ductile iron seems to consist of innumerable plicæ, lamellæ, filaments, and series, which are made continually to stretch themselves and rub one another by frequent tensions; hence they begin not only to be contremiscent, but incalescent, and thus to be ready on the slightest application of the magnetic element, or else of their own accord in virtue of their mechanism, to pass consentaneously into a state of orderly arrangement. For by reason of the tremors and of the caloric, the parts become as it were left to themselves; because they become more free, are more at their own disposal, more obsequious to every natural motion, and consequently disposed to flow consentaneously into an orderly position. And if under the regular blows of the hammer, or the operation of the file, the same contremiscence and calescence be superinduced, so also, if the artizan be skilful, the parts can be made to assume a regular position suitable to magnetism. *Experiments of this kind afford additional evidence in favor of our first principles; namely, that all magnetic force consists entirely in the regular arrangement of the parts, and that all effluvia from iron are magnetical* [mere magnetica]. *From these data flow, by mechanical*

order, all that we have hitherto ventured to maintain, concerning the modes and qualities of the magnetic forces in the magnet and iron. Let experiments, however, speak for themselves.

A POSTERIORI OR FROM EXPERIMENTS.

The magnetic virtue is universally present, though latent, in every body made of iron. Whether great or small, thick or thin, the iron evidently shews its attractive force which it exercises upon filings, Virginian sand, or the magnetic needle ; and frequently possesses a directive force, by reason of which, when left to itself, it turns to the same quarter of the heavens as the magnet or the needle. This need not excite surprize ; inasmuch as we have before observed, that iron through length of time corroded with rust and infused into the pores of a stone, changes into a genuine magnet. Nor indeed need we be at much pains to find a magnetic force in bodies made of iron ; for every ploughshare, scissors, shears, nail, wedge, needle, or other manual instrument of iron, attracts at any point or angle of itself Indian sand or iron filings. This was known in the past age to many, particularly to the studious and learned Gassendi and Rohault ; while in the present day it has been further confirmed by Wolffe and Reaumur in *l'Hist. de l'Acad. Roy.*, A.D. 1723. Being about to treat of the magnet and its forces, I have thought it right not to omit the observations which have been taken with respect to the force of iron ; since they are of the same nature as the former, and may throw some light upon them. Moreover as many of those things which were formerly affirmed of the magnet, I have either confirmed by submitting to a fresh examination, or else have found to be erroneous ; so, in the present case, I have pursued the same plan by reëxamining the discoveries of others, supplying their deficiencies, omissions, or oversights, and reducing to order what had laid scattered through the writings of different authors. These observations I have premised, lest it should be thought I was propounding trite remarks ; or passing off as my own the experiments of others.

EXPERIMENT CXXXI.

A cylindrical iron rod, $\frac{1}{12}$ inch in diameter and 6 inches long, was placed upon a bright fire, so as to lie longitudinally in the meridian passing through the north and south poles. The fire was not made in the vicinity of other iron, but only where stones were laid, lest the force of the former should disturb the experiment. Being made red hot throughout its entire length, it was taken out of the fire with a brass tongs so gently as to experience no concussion; and was then immediately brought in a horizontal position near a moveable needle endowed with magnetic force; in doing which care was taken so to convey the rod as to keep it in the same meridian. In this case the southern end of the rod attracted the northern pole of the needle, and the northern end of the same rod, when turned, attracted also the northern pole of the needle.

2. In the place of this slender rod, we next took another of a diameter twice as large, and 10 inches long; this we employed in a fresh experiment, after being well heated in the fire; and then, when taken out and opposed to the needle, it exhibited at its extremities the same effects of attraction as the former.

3. Nay further; an iron parallelopipedon, which was 5 inches long and 1 inch square at the base, evidently furnished the same results.

These experiments may be made with a needle enclosed in a brazen capsule and covered in with glass; for the fire escapes with such great impetuosity from the iron under examination, and so shakes the needle if unprotected, that tremors, oscillations, and other inordinate motions, are induced upon it; which impede the taking of any observation with regard to the attraction.

The magnetic force therefore, whether in a stony or iron substance, acts upon ignited iron by attracting it; for that a magnet attracts red hot iron is confirmed by Colepress in the *Philosophical Transactions;* by Muller in *Col. Phys.*, p. 229; and by our own experiments adduced in Chapter II. We here observe then, that the magnetic force of the needle operates upon ignited iron; and this we state in opposition to Gilbert, who denies the fact in book ii., chap. ii., p. 52.

2. We remark also, that in ignited iron there is no directive force; for if red-hot iron had poles, it would not attract indifferently either pole of the needle. But although one of the pieces of iron might exhibit this property, yet it might not obtain in the other two; for we confess that notwithstanding we may sometimes find wires both of whose extremities attract the same pole of the needle, this occurs but seldom. And yet this we observed, on three different occasions, in the case of hot iron, and never otherwise. Therefore there is either no directive force in hot iron, or else it is infinitely small.

EXPERIMENT CXXXII.

If extremely thin iron rods, such as were used in experiment 131, be made red hot; and then without any concussion be carefully extracted from the fire with a brazen tongs, and be made to lie for the space of an hour in the terrestrial or magnetic meridian, upon a stone floor; and if the northern end be placed at the south pole of the needle, then it will attract the latter but repel the north pole. The southern end of the rod will however attract the north pole of the needle, but repel the south pole.

If any long cylindrical slender rods, such as those over which the curtains of windows or beds are drawn, lie for some time in a direction parallel to the horizon, in the terrestrial or magnetic meridian; then, whether they are upon the ground or are placed higher up and suspended in the air, they are imbued with the same directive magnetic force; and with the ends which have been turned to the north they attract the south pole of the magnetic needle and repel the north.

I will here add an observation from which it will be evident, that philosophers have for the most part too generally determined the properties of the magnet, without having faithfully and accurately noted all the circumstances attending their experiments; which nevertheless it is desirable they should have done. It is for this reason, that having been much versed in making these experiments, I have detailed every particular without the smallest exception; and hence to some persons I may appear to be exceedingly prolix; although unless the several details are noted down and compared one with another, we necessarily fall into error. Any one therefore on first reading over these experiments, might not yield to the opinion that iron placed in the meridian is impregnated with a directive magnetic force. Let him not however be too precipitate; for these experiments are made only with long and slender rods; but will the same phenomena obtain in thick ones? Let us enquire into this subject; a task which will repay our labour; for in iron 1 inch in diameter or thicker, but shorter than 8 or 10 inches, I could never observe any directive force of this kind, even though it lay in the meridian for some days.

Let us observe the analogy between the force of the magnet exercised upon iron, and the universal magnetic force, as resulting from a magnet supposed to be enclosed in the centre of the earth exercised upon iron. The magnet requires iron lamellæ of only a certain thickness, to which it communicates its force; lamellæ which are thicker, being not susceptible of any impression. In like manner that iron is required to be of a certain length and thickness, which, when left to itself, spontaneously acquires a magnetic force. I doubt not but that all iron, however thick, may be impregnated with a magnetic force; provided it be sufficiently long. But there is required a certain proportion between the thickness and the length; and what this proportion is I know not, as we are in want of experiments from which to deduce it.

The authors of the foregoing observations add, and rightly, that red-hot iron, placed in the meridian, is more quickly endowed with a directive magnetic force than iron that is cold. Slender and long pieces of iron therefore spontaneously acquire a directive force by which mariner's needles or compasses are acted upon, provided it has laid some time in the meridian. Hence we can obtain a needle without the aid of a magnet, and ascertain its directive power. Take, for instance, a slender and long rod, passed through the middle of a small cork so as to float on the water in a large bowl, situated in a quiet place; you will see one end of the iron turn toward the north, just as in the case of the needle; this conversion and direction however are attained by a very slow motion. The same result is observable, if we suspend a rod by an extremely fine silken thread not twisted; as we are informed by Gilbert, book i., chap. xii., p. 32. The force therefore which the interior magnet of the earth communicates to the iron, is not immediately destroyed, but remains for some time; and causes that part of the iron which last faced the north to become turned to the north.

EXPERIMENT CXXXIII.

Having in our preceding experiment examined iron that had been laid in the meridian, we now had to ascertain what occurred in iron laid parallel to the equator of the earth, and in a position cutting the meridian at right angles. With this view an extremely slender iron rod, such as was used in experiment 131, was made red hot; it was then drawn out so as to avoid any concussion, with a pair of brass tweezers; and was left to cool upon a stone floor, in a situation parallel to the equator of the earth, and at the same time in the plane of the horizon. When cold it attracted the south pole of the needle, and repelled the north with the end which had faced the west. But it required to be brought an inch nearer to the needle than before, in order to enable it to manifest its virtue; so that after cooling in this position, it was found to have acquired a weaker degree of force than after it had laid in the meridian. I had before seen the forces of the western cusp attracting the south pole of the needle. For in this part of the world, and in the present year, the magnet declined toward the west 13° 20′; and therefore when the rod was placed parallel to the equator of the earth, the western cusp remained in the northern hemisphere of the magnetic forces; and hence, having acquired the force and direction of a north pole, it could not but attract the south pole of the needle, and repel the north.

2. The magnetic equator having been accurately marked out on a stone floor, the same rod, which had first been made red-hot, was left to cool in the equator ; and after this it attracted with each end the north and south pole of the needle ; so that the rod manifested a perfect indifference, being endowed with no poles ; a result which could not but ensue.

3. The same rod, after being made red-hot, I again placed upon a stone floor so as to cut the magnetic meridian at an angle of 45°, and with one end to face the north-east, and with the other the south-west. The western cusp of the rod when cooled, attracted the northern pole of the needle, producing no effect upon the southern. The eastern cusp of the rod attracted the southern pole of the needle ; producing no effect upon the northern. These experiments were conducted with the greatest care, in a place free from the vicinity of all iron. In the attraction of the cusps there is nothing anomalous ; for in sec. 3, the southern cusp became a south pole, attracting therefore the north pole of the needle. But the indifference of the other cusp of the rod is more difficult to be understood, because this shews the repulsion to be equal to the attraction ; and hence this cusp was bipolar in respect to the south pole. The case was the same with the other cusp of the rod ; for this was indifferent in respect of the north pole, but attracted the south pole of the needle ; and this cusp was therefore bipolar in respect of the north pole ; the attractive force of one being equilibrated by the repelling force of the other. Thrice happy the man who can clearly understand and explain these phenomena ! Doubtless the task will be extremely easy to those who are already well acquainted with the natures of bodies, and who are consequently enabled to decide even now upon the subject ; although to ourselves it is one which is not intelligible at present, in consequence of the cloudiness of our reason and the obscurity of our mathematical ideas.

EXPERIMENT CXXXIV.

A slender long iron rod, such as was used in experiment 131, was made red-hot and taken out of the fire with a pair of brazen tongs ; it was then plunged into water in a position parallel to the horizon, and in the magnetic meridian. The north pole of the iron when cold immediately exhibited the force of a north pole, with which it attracted the south pole, of the needle ; the southern end attracted the north pole of the needle. The attractive force of the rod, after being plunged into water, was much greater than when, as before, it had been left to cool on the floor. This has been noticed not only by myself, but by Gilbert, Rohault, Boyle, and Wolffe. Reaumur, however, has lately called the observation into question in *l'Hist. de l'Acad. Roy.*, 1723; affirming that he had often made the experiment but had never found immediately after the extinction of the iron any magnetic force. He therefore suspected that Gilbert and Rohault had not used sufficient caution in conducting the experiment, and that the iron, on being plunged into the water, had been made to experience some degree of concussion; for he had observed that concussions produced by the hammer or otherwise, were apt to impregnate the iron with magnetic force. What are we then to say in this matter? On which side lies the truth? Experience tells us, that Gilbert, together with those who agree with him, and also that Reaumur, had the truth on their side. Here lies however the subtle cause of the difference. If we take a long and slender rod, such as we used in experiment 131, there will always be found in it, immediately after its extinction in water, a very considerable magnetic force; while a portion of the same rod to the extent of 1 inch only, or a rod of a greater thickness and at the same time very short, after extinction in water, never acquires any magnetic force observable to the senses. Hence it is certain that Reaumur in his experiments used rods which were too short and thick; in which therefore no magnetic force was perceptible. Gilbert, Rohault, Boyle, and Wolffe, instituted the experiment with slender and long rods; and hence were led to think that a magnetic force obtained in all ignited iron after extinction in water. From controversies of this kind we learn with what care it is requisite in experiments to attend to all the circumstances of the case; that many of these experiments have been performed too hastily, and described with more brevity than is desirable. We learn also how little we are at liberty to reason in physics; and from one kind of observation to deduce a general conclusion; for this it is which in the foregoing instance has led all the learned into error. The particular observation which all had made in regard to the particular piece of iron was true, let the experiments have been made by whom they might; and yet the observation was not true as applied to every other piece of iron of whatever length or thickness.

I have since found the same kind of remark in the *Philosophical Transactions*, n. 214, A.D. 1694, by an anonymous writer, who, to the observation of Gilbert, adds the following reflections. "But this obtains only in certain cases; for when the rod is short, a pole cannot be formed in this manner. Take a round piece of wire, $\frac{1}{3}$ of an inch in diameter and 10 inches long; in this case no pole can be produced, even though the piece be subjected to the fire: but if the wire be longer, as for instance, 30 inches, then if ignited, it is capable of exhibiting a pole. In like manner if we take a round rod, 1 inch in diameter and 30 inches long, it will not be adapted to the formation of a pole." He next adds, that "no rod can be too short for exhibiting a pole, provided only it be sufficiently slender. The degree of length required in proportion to the thickness increases more than we imagine." I wish this accurate writer had subjoined his experiments; but he seems to have purposely omitted them as being useless; although in my opinion they would have been of the greatest service.

EXPERIMENT CXXXV.

The slender iron rod, which I had used in experiment 131, I again made red-hot, and took it out of the fire with a brazen tongs, holding it horizontally; so that it should be always in the same terrestrial meridian. That half of the rod which pointed to the south I plunged into water; keeping it almost in a horizontal position; after which the southern end of the rod and the northern attracted the north pole of the needle.

This rod was again made red-hot; the one half of it which was held pointing to the north, was plunged into water, the other half remaining out of the water. In this case the northern cusp of the rod repelled the northern pole of the needle, and attracted the southern; phenomena which will be better understood after the explanation of our next experiment.

EXPERIMENT CXXXVI.

A slender oblong iron rod was made red-hot, and taken out of the fire by a brazen tongs, with which it was held perpendicularly to the horizon. The inferior cusp of the iron, even when red, strongly attracted the south pole of the needle, and repelled the north; but the superior cusp attracted the north pole of the needle and repelled the south.

Thus the ignited iron became immediately endowed with a magnetic force, when held in this perpendicular position; and as quickly as if it had been rubbed against a magnet.

2. This rod was left in the same perpendicular position for the space of an hour, and then exhibited the same influence upon the needle as

before; with the exception that it did not so strongly attract it, now that it was cold, as when it was ignited.

3. The same rod was again made red-hot and plunged perpendicularly and entirely into the water; in which case its inferior cusp became a north pole; for it attracted the south pole of the needle with a strong force. A repetition however of these ignitions, and extinctions in water, did not appear to increase the attractive force of the rod.

4. Finally, the same rod when heated was plunged perpendicularly into the water to half its length; when the inferior cusp, on being extinguished, became a north pole; and the superior cusp, immediately after extinction, attracted equally the north and the south poles.

5. In the next place there was laid perpendicularly upon the ground an ignited parallelopipedon, 5 inches long, with a base 1 inch square. After the lapse of an hour, when it had cooled, the inferior base attracted the north pole of the needle, which was attracted also by the superior base. Hence in this short parallelopipedon of iron, the directive magnetic force is not collected within so brief a time as in more slender rods. Nor indeed is it collected in iron of this thickness suddenly, even though it be plunged into water.

We may however observe in regard to all iron, not excepting the thickest; nay, even in regard to those pieces which could not by the magnet be impregnated with magnetic force by reason of their size; that when placed in a position perpendicular to the horizon, they become spontaneously endowed with a magnetic force: the thick and short not till after some length of time: the thick and long, more speedily: but the slender and long did not require a minute. For if we take a rod 6 feet long, and $\frac{1}{5}$ of an inch in diameter, and hold it perpendicularly to the horizon; then with its inferior cusp it will attract the south pole of the needle and repel the north; and with its superior it will attract the north pole of the needle and repel the south. Now immediately invert the rod, and within a minute you will perceive that the inferior cusp will attract the south pole of the needle which before it had repelled; so that in a rod of this kind, the poles become most rapidly changed. The same phenomena may be observed in a shorter but much more slender rod. Some of these phenomena Grimaldi had formerly noticed in his treatise on *Light*, prop. vi., sec. 51; as also Boyle, and likewise Polinieri in his *Exper. Phys,*, p. 283; and more recently Reaumur in *l'Hist. de l'Acad. Roy.*, A.D. 1723. We must likewise add, that sometimes there are steel lamellæ which, when ignited and plunged perpendicularly to the horizon into water, acquire fixed poles unsusceptible of being changed, turn them in whatever direction we may. There are also others which preserve their poles fixed, but when inverted do not exert so strongly the force of the same pole as before; and manifest at last rather an inclination of the same pole; nay, others there are which, after being turned, become indifferent; so that when brought near the mariner's needle they direct it eastward and westward; and thus as it were maintain it in equilibrium. These phenomena however obtain only in slender steel lamellæ; for in thicker pieces of iron those only obtain which I have above adduced. The principal part of this observation may be seen in the *Philosophical Transactions*, n. 246.

If the pieces of iron remain for some time fixed, (as, for instance, the iron lattice-work of windows, which in old houses has lasted for hundreds of years,) then do these acquire a most considerable power of operating upon the needle, even at a distance of 4 ells and more; as Cabæus observed at Mantua, book. i., chap. xvii.

From these experiments it is evident, that a needle may always be obtained which shall direct its extremities toward the northern and southern part of the heavens, although it be not rubbed against a magnet; provided that for some time it stand vertically erect, or when ignited, be immersed in a perpendicular position, into water.

If a longer rod be chosen for these experiments, the point attracting the north pole of the needle will be always more distant from the extremity of the iron than the point which affects the south pole of the needle; as was formerly observed in the *Philosoph. Trans.* for 1694, and as Reaumur also has recently stated.

It is moreover a circumstance worthy of admiration, that ignited iron, placed perpendicularly to the horizon, becomes imbued with a magnetic force; although the magnet itself when made red-hot and afterwards placed in a like perpendicular position, while cooling, neither retains nor acquires any virtue. With a view to ascertain this fact, Boyle took some oblong magnets, which he made red-hot and then allowed to cool, after laying them in a north and south direction, and either in a horizontal, perpendicular, or other oblique position; but he could never observe any directive or attractive force remaining in them. See his remarks concerning Magnets, p. 499.

EXPERIMENT CXXXVII.

The same extremity of the needle is attracted in different ways, in different places of the earth, by the same extremities of the iron rod, when held perpendicularly to the horizon and opposite to the needle.

This is evident from the observations taken by a navigator, inserted in the *Philosophical Transactions,* n. 177; and which I think ought not to be omitted; as I have never met with any other person who has instituted similar ones. They were written in the year 1684, by a navigator who crossed the equator.

1. From England as far as 10° north latitude, the north part of the needle attracted the superior extremity of the iron rod. The south part of the needle attracted the inferior extremity of the rod.

2. At a north latitude of 9° 42′, and at a longitude westward of Lizard, the southern extremity of the needle strongly attracted the lower end of the rod; but the northern extremity of the needle did not attract the upper part of the rod so strongly as in the case preceding.

3. At a north latitude of 4° and 33′, and at a longitude of 5° 18′ westward of Lizard, the north part of the needle began to decline from the upper part of the rod, and the south part of the needle more strongly inclined toward the lower part of the rod.

4. At a latitude of 0° and 52′ south, and at a longitude of 11° 52′ westward of Lizard, the northern extremity of the needle was not attracted by the upper part of the rod, nor was it sought by the inferior part of the latter; the southern extremity of the needle however inclined to the inferior part of the rod, although not so strongly.

5. At a latitude of 5° 17′ south, and at a longitude of 15° 9′ westward of Lizard, the southern extremity of the needle was turned to the inferior part of the rod; nevertheless it did not seek the upper part of it, which likewise was not attracted by the north extremity of the needle. But when the rod was placed horizontally in a line parallel to the terrestrial meridian, then the northern extremity of the needle was turned toward the southern extremity of the rod.

6. At a latitude of 8° 17′ south, and at a longitude of 17° 35′ westward of Lizard, the northern extremity of the needle did not seek the upper part of the rod, but rather shunned it; the southern extremity of the needle however in some measure sought the lowest extremity of the rod, and changed its true position about two points. The rod was next placed over the needle, so that the uppermost part of the rod faced the southern pole of the heavens, and the lowest part the southern pole; in which case the north part of the needle sought the lowest part of the rod, and followed its motion; but when the rod was placed horizontally, the phenomena were the same as above.

7. At a latitude of 15° south, and at a longitude of 20° westward of Lizard, the southern extremity of the needle began to seek the upper part of the iron rod, and the northern extremity of the needle attracted the lowest part of the rod, which it followed; but when the rod was

placed horizontally, then the northern part of the needle sought the southern part of the rod.

8. At a latitude of 20° 20′ south, and at a longitude of 19° 20′ westward of Lizard, the southern extremity of the needle sought the upper part of the rod, and the northern extremity sought vehemently the inferior part.

9. The same results took place at a latitude of 29° 25′ south, and at a longitude of 13° 10′ westward of Lizard.

These results we might have determined *à priori*, after it was known that the northern extremity of the needle, in the northern hemisphere of the earth, inclined downward toward the horizon; that in the southern hemisphere of the earth, the southern extremity inclined downward, and the northern upward; because the north pole of the terrestrial magnet prevails in the northern part of the earth, and attracts to itself the northern extremity of the needle; but in the southern hemisphere, the southern pole of the same magnet prevails; whence it determines the southern extremity of the needle towards itself. Since therefore, by experiment 136, the inferior cusp of the rod when held perpendicularly in this region, attracts the southern pole of the needle; it is impressed by the terrestrial magnet with the force of a north pole; — and for this reason, that the inferior part of the rod is nearest to the north pole, and will therefore receive the virtue of this pole as long as it is nearer to this than to the south pole of the magnet; but as soon as the inferior cusp of the rod approaches nearer the south pole of the terrestrial magnet, it will receive the force of the latter, which is plainly opposite to the former; and therefore the inferior cusp of the rod will attract the north pole of the needle. But in that part of the earth in which the force of each pole of the terrestrial magnet is equilibrated, the inferior cusp of the rod will not be endowed with any force; and therefore it is that the inferior cusp of the rod was observed to be impregnated with the force of the north pole of the terrestrial magnet in the northern region of the earth, as far as a south latitude of 8° 17′; because the force of this magnetic pole extended itself to this distance. Beyond however a south latitude of 15°, the force of the south pole of the magnet began to predominate; and communicating its virtue to the lowest extremity of the rod, caused the latter to attract the north pole of the needle; the virtue of each magnetic pole was commonly in equilibrium from a south latitude of 0° 52′ to 8° 17′; hence each extremity of the rod was endued with scarcely any magnetic force. We have seen, in the inclinations observed by Noel (?), that the inclination of the needle is perpetually diminished from the north latitude of 38° 40′ to the south latitude of 6° 30′; a sign that the force of the north pole of the terrestrial magnet extends itself hither; but on receding hence more from the equator to the south, the inclination of the needle was inverted, and the cusp which faced the horizon in the northern part of the earth, was now directed upward; the pole of the southern magnet predominating; the force of which continued to increase until, at the latitude of 35° 25′, it reached its maximum and erected the needle perpendicularly to the horizon; therefore also in the present observation it was rightly noticed, that at a south latitude of 20°, and farther to 29°, the inferior part of the rod strongly appetited the northern cusp of the needle; nay, the force was observed to be the stronger according as the experiment was taken in a greater southern latitude, 35°, and in the same longitude with that of Madagascar.

EXPERIMENT CXXXVIII.

An iron rod was placed upon an anvil, so as to be in a position parallel to the terrestrial meridian. The extremity facing the north, when struck with a hammer, became a north pole; the southern extremity, when struck with a hammer, became a south pole. This experiment however succeeds only with rods of a certain length and thickness, and not with all. For if a rod were too thick in proportion to its length, then, although either extremity were struck with a hammer, the directive force of the poles would be observed to be none, unless the extremity were so attenuated that the slenderness of the rod maintained a certain proportion to its length. All that we have said concerning the effect produced by a hammer, is to be understood as produced by a file passed over the iron, or by rubbing the iron upon any hard body, or by cutting it with a saw; provided the iron be long and slender. The stronger the force with which the forementioned instruments come into contact with the iron, the greater is the degree of magnetism induced; and yet the magnetism never increases to such a degree as may be communicated to the iron by a magnet of moderate power. As in hammering the rod upon an anvil, we induce upon one extremity a north pole, and upon the other a south pole in this part of the world; so we ought to pursue the method which is pointed out by the inclination of the needle. The south part of the iron upon the anvil should be considerably more elevated; the north part more depressed: in this manner a rod when hammered will always have two poles at its extremities.

But if the iron be held upon the anvil in a different manner, sometimes we shall perceive at each extremity a north pole. Similar remarks may be observed in the *Philosophical Transactions,* No. 214.

EXPERIMENT CXXXIX.

Let a lamella of very soft iron be held between the teeth of a pincers, so as to project beyond it; let it next be forcibly bent to the right and left, until it is broken. The fragment will then attract the filings of iron, just as if the lamella had been impregnated with the force of a weak magnet.

Reaumur conducted this experiment with large pieces of iron; with wire made of the best iron, and also of iron soft and fragile; with tempered steel, and with steel not tempered. Other things being equal, the softer the iron that is broken, the more fibrous it is and the more flexures it requires to break it; but in this case the greater is the attractive force that it acquires. Fragile iron, very soon broken, is impregnated with a less degree of force; and with a still less, steel that is well tempered; with regard to the latter, the softer or harder it is, the more strongly or weakly it attracts. In general all iron broken, by being bent becomes endowed with a magnetic force, which sometimes however lasts only for the space of a day. The author likewise records that the attractive force is not sensible, if the iron have only the thickness of a needle; and that the force is not increased in the ratio of the thickness of the laminæ, but is greatest in iron of the thickness of the little finger. In these experiments we see a determinate length of iron required. For bend and break in the middle iron a foot long, and both fragments will manifest a magnetic force; but when the iron is so broken that either fragment is not more than a digit in length, then it will not attract the filings, however fine; while the other and longest fragment will attract it with great force.

In these experiments the broken end alone acquires a magnetic force; the other extremities remaining such as they were before the experiment.

EXPERIMENT CXL.

For many beautiful experiments with iron we are indebted to the sagacious Reaumur, and among others for the following. If an iron wire about the thickness of the little finger, and 2½ feet long, be held by a pincers; and if by frequent bendings it be broken 5 digits from its extremity, then each surface of the fracture has only so much magnetic virtue as will be able to lift a small nail.

If the longest fragment, inserted into the teeth of the pincers, be frequently bent at 1½ inches from the fracture, yet so as not to break it; then the surface of the former fracture has acquired a greater force of attraction. After this, if we bend the iron in other places, but always nearer to the middle, we find its magnetic forces increased. In eight places bent in this manner, the former fracture had acquired so great a force as to be able to lift four nails. On continuing the flexions from the middle of the iron to the opposite extremity, and as often examining the force of each extremity, we find the magnetic virtue of the fracture decreases; while that of the other extremity at the same time increases; until after numerous flexions in various places of the iron, the extremity acquires a power capable of elevating four nails, while the superficies of the fracture is then capable of carrying only particles of filings.

EXPERIMENT CXLI.

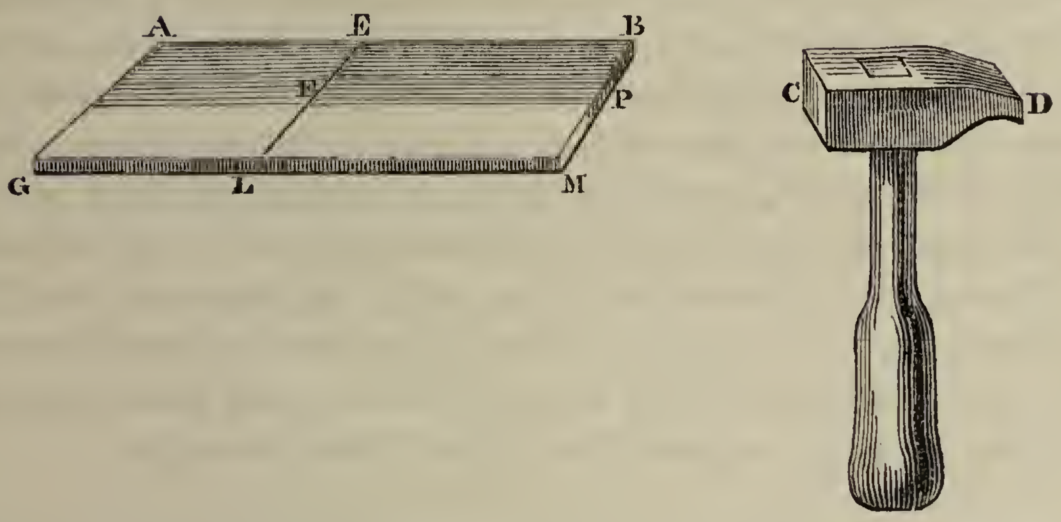
If a piece of iron wire be frequently bent in the middle, its two extremities do not acquire any manifest force. Let us conceive divisions to be marked from the middle of the iron toward each extremity, at equal distances one from the other; and let the iron be bent at the two divisions one each side of the middle, and equally distant from it, reckoning from the middle; then both extremities of the iron will acquire a magnetic force; but weaker than if the flexures had been made in one part at the middle; nay, so weak will be the force of each extremity, that it will not equal ⅓ or ¼ of that which it had, when the flexures were made at the half division of the iron.

EXPERIMENT CXLII.

If by various inflexions iron wire be endowed at either of its extremities with a considerable attractive force; and if it next be bent in other places also between the same extremity and the middle dividing mark; then the attractive force of the extremity, so far from being increased, will be rather destroyed; in like manner as I have before observed, that the force, pertaining to wire rubbed against a magnet and then frequently bent, is also destroyed.

EXPERIMENT CXLIII.

Fig. 83.*



We shall here notice a paradox concerning iron; which, according as it is hammered in different ways, differently exhibits a magnetic force. If a thick iron plate [*regula*] AGMB, be hammered upon an anvil with the broad and plane part of the hammer C, it will acquire no attractive force; if however it be hammered with the narrower part D, proceeding from E to B, the extremity A will acquire a certain force, although feeble; but nowhere else will any force be observable, or in any part around the hammered places. Next let the strokes of the hammer be directed along the middle of the length FP, taking care that the parts FEBP are not hammered, or FLMP, with the exception of the small rectilinear part FP; and then both the angles A and G will be endued with a magnetic force; but not the middle part between AG.

EXPERIMENT CXLIV.

As soon as any iron tool cuts a piece of cold iron, it acquires an attractive force; if it cuts or abrades iron red-hot, it loses none of whatever force it may have had before. If a wedge of steel, endowed with a magnetic force, be struck by a mallet and made to cut red-hot iron, then will the wedge lose its magnetic force.

EXPERIMENT CXLV.

Iron bodies which end in a point, acquire a greater magnetic force than those which end with a broad or plane surface. Hence it is that an auger attracts with its point more than a knife [*culter*]; the shorter the auger is, the less is the force with which it is endowed; for Reaumur has observed, that an auger 1 inch long and 9 lines diameter, although it easily perforated iron, yet would attract only a few raspings; while on the other hand, an auger 3 or 4 inches long, and a line or 1½ lines in diameter, attracted small nails. Augers however appear to experience increments of their attractive forces in the act of circumflexion, while perforating iron, copper, or stone; as is rightly noticed by Hook, in the experiments published by Derham, page 128; by Ballard, in the *Philosophical Transactions*, No. 246; by Reaumur, in *l'Hist. de l'Acad. Roy.*, A.D. 1723. Hence it is no wonder that filings which have come in contact with the auger, and which have been scooped out of a hole, possess a magnetic force derived from the auger.

---

* In the original, plate XVII., fig. 4.

EXPERIMENT CXLVI.

All new tools of tempered steel, clenched by a pincers, and strongly rasped until they begin to grow hot, possess a great attractive force, and even greater than when cool.

Every steel body rubbed strongly upon the ground till it acquires a considerable degree of heat, shews a manifest attraction; which nevertheless it loses as soon as it grows cold. This was known to Boyle, and was described by him in *Mechan. Prodrom. of Magnetics*, sec. i., page 497; and by Ballard, in the *Philosophical Transactions*, No. 246; who adds, that by the attritus the poles of the iron are changed; for that he rubbed a knife upon a magnet, whence the point of the knife became a south pole; but when the knife was strongly rubbed against hard and dry wood, so as to produce considerable heat, the point lost the force of a south pole, and changed into a north pole; a circumstance which he found continually recurring on frequently repeating the experiment. This however, we should observe, takes place only in a thin knife; for a thicker one does not by attritus lose the poles which the magnet had impressed, the parts not having experienced sufficient concussion.

This subject however may be amplified, and deserves to be so, with additional observations concerning the attractive and directive forces of iron; for they may occasionally afford considerable light in tracing out the cause of magnetism. I have already however been sufficiently prolix; for it was not my intention to write a volume, but only a brief dissertation. The observations which I have here recorded are only the first-fruits of enquiry, and such as have been discovered or demonstrated in our own age; to which I will add, in the way of coronis, another which I have often observed confirming the existence of a universal directive force. The extremely small scales of iron, which, when iron is hammered, fall from the anvil in the blacksmiths' shops, all attract one another, and receive a direction to the northward or southward in a line according with the magnetic meridian; provided the floor on which the anvil stands is plane and made of wood.

From these experiments we collect, that the force of the magnet enclosed within the earth is very universal; that it extends itself throughout every quarter of the globe; that it acts upon all iron, and imparts to it a direction in accordance with what we have above said, viz., that iron is attracted and governed by the magnet.

But the way in which this great magnet has come to acquire its virtue, can by no means be deduced from any observations hitherto recorded. Wherefore other experiments must be instituted by posterity, in order to put us in possession of our wishes, and to solve a problem hitherto so intricate and abstruse. The true method will be by philosophers becoming observers, and subjecting the magnet to various experiments, unmixed with any speculations of their own or fictitious hypotheses; for these, assuming as they do only deceitful smiles, retard all further experiment and progress of science, inasmuch as they affect to be the solution of the problem. These hypotheses, however numerous, have hitherto served no useful purpose; have obscured the intellect by their noxious fumes; and have only compelled succeeding and more prudent enquirers to institute fresh examinations. Nor indeed upon this subject does the opinion of the wise Fontenelle differ from our own; who, in *l'Hist. de l'Acad. Roy.*, A.D. 1723, after a beautiful explanation of the hypotheses and experiments of Reaumur, adds, that philosophy would have been best contented with his labours, had he only discovered all the phenomena of the magnet. For what is the use of hypotheses, however subtile and ingenious, if they cannot explain or geometrically demonstrate phenomena. When the phenomena are discovered, the cause will no longer be latent; and when the cause is found and properly understood, all the phenomena will be mathematically proved, and the doctrine of magnetism may then take its place among the parts of mixed mathematics. In the meantime, one thing may be considered as demonstrated; namely, that this stone, endowed with such wonderful and widely diffused virtues which have never yet been comprehended by the most sagacious mind, cannot consist of any fortuitous collection of brute atoms, nor have originated from a cause endowed with less virtues, but from one far more excellent —the fountain-head and origin of all things, of all bodies, and of all forces; whose Infinite Wisdom produced nothing but what breathes of wisdom; and whose stupendous works it is given to finite and puny mortals to behold, to admire, and to venerate; in order that from these it may be the more evident, that there is a God endued with attributes, every one of which is infinite; and who has created this stone, as He has all other things, in unspeakable profusion; and given it to mortals, in order that by its aid the mariner may without uncertainty navigate the vast oceans leading to the remotest countries, and carry to and fro from the most distant regions the vegetable produce and mineral riches of the earth; so that all the different races of mankind may become acquainted with the nature of its treasures, and apply them universally to use.

APPENDIX.

Such are the experiments adduced by that very able philosopher, Peter Van Muschenbroek, in his *Experimental and Geometrical Physics;* experiments, the reasons and causes of which, as derived *à priori* and from first principles concerning the magnetic forces, it has been my wish to subject to examination: an examination from which we may perceive, that magnetism consists only in the regular situation of the parts; through the medium of which a perfectly regular sphere may be formed both around the magnet and around the iron. To each of these experiments I might have added my own remarks, and thus have rendered the causes still more evident; but this was superfluous. Indeed what proof can be plainer than the one derived from iron filings sprinkled round the magnet? which in a continued line follow the course of the magnetism, and dispose themselves into a like situation and track with those of the smallest parts in the iron, which, if we could view them with the help of glasses or with the bare eye, would appear to be disposed in like manner; so that in filings we may see the effigy of the parts in the iron which are arranged into a regular order at the will of the magnet, and hence assume to themselves a magnetism. Could we also artificially dispose steel pollen into the form of a mass, and over it move the magnet, we should have ocular evidence that every atom betook itself into that situation into which the smaller parts of iron when rubbed are disposed; that is to say, into a regular situation. If this situation of the parts in the iron be disturbed either by too frequent bendings, or by too hard blows, or by fire, then the iron immediately divests itself of its magnetism and assumes its own pristine character; as is evident from many of the experiments of the forementioned author, Chapter XI. From these also it follows, that the effluvia are the similar and the smallest parts of iron; which in consequence of a regular disposition of like parts in the confines of the body, and of their being a most subtile element, create a regular sphere around the magnet;—a sphere which could not be created without a regular disposition and nexus of the parts on all sides with the magnetic or iron body. Nor do I know that there either is or can be any documentary evidence extant, which does not attest and confirm the fact, that it is in these things that the active forces of the magnet consist.

CHAPTER XIV.

THE DECLINATIONS OF THE MAGNET, CALCULATED UPON THE FOREGOING PRINCIPLES.

ORDER now requires us to treat of the declination of the magnet, and first to explain theoretically the cause of the declination, and the origin of its variation. The surprizing and well-known phenomenon of the magnetic needle, and the amazing *lusus naturæ* it presents to view, could not but be the source of perplexity to the minds of many; for the declination not only varies in every place, and in every part of the earth is dissimilar to itself, but undergoes also an annual mutation. This for a long time has served as an apple of discord; but whoever shall succeed in gaining possession of it, will also succeed in carrying away the palm. The discovery of this secret will indeed be of immense service to the world, particularly to mariners; who will consequently know the declination of their needle, and in some measure become acquainted on their voyage with their bearings eastward or westward; that is to say, with the longitude. Before however we come to the reasons and causes of the variations, and of the surprizing change and inconstancy of the magnet, it may be well to explain the practical difficulties of making observations, and to shew the doubtful and equivocal character of those which have hitherto been made. For with the exception of those which have been instituted at Paris, London, Berlin, and a few other places, no perfect reliance can be placed upon them: indeed it is questionable whether the tables do not differ from the true declination of the place either by half a degree, a whole one, or even one and a half; so that whoever shall assume all the observations to be true and undoubted, and make them serve as the basis of his calculations, may deviate very widely from the truth. The principal causes of the difficulty in making observations, as known to the learned world, may thus be pointed out.

1. Should the least portion of iron be anywhere in the vicinity, immediately the needle, which has to indicate the declination, deviates from its true magnetic meridian, and moves in that direction more or less sensibly; nor is it disposed to return to its proper meridian, adopt what expedients we may; neither can the observer foreknow the particular quarter in which the portion of iron is latent, and consequently he must be ignorant whether the needle occupies its true meridian or some other which is not the true one. It is well known that in all matter there lies concealed some portion of iron; as, for instance, in metals, stones, wood, and the earth; hence if in the box, or in the brass or copper of which the box is made, any iron be latent, immediately the needle may be displaced from its true meridian. Experience proves that small parts of iron in copper may attract the needle; consequently if the slightest particle of iron be anywhere in the box, the meridian of the declination becomes immediately doubtful and undeterminable. If there be no iron in the box, but particles of iron latent in the post on which the capsule with the needle is placed, or in any contiguous wooden, stony, or calcareous substance, the magnet immediately deviates and becomes hallucinated. Iron lies concealed in wood and stone; particularly in the calx and stone of brick; because each consists of clay, which, when calcinated and burnt, melts the parts of iron and secretes them within. I shall say nothing of nails in windows and shutters, of lattice-bars, and of other pieces of iron which are often visible to the naked eye. These, although situated at several inches distance, are capable of deflecting the magnet from its true meridian. Should there be in the vicinity a mineral mountain impregnated with any portion of iron, or should the earth contain a portion, and the air be consequently filled with its effluvia, the needle immediately deflects itself from the true meridian, and advances one or two paces; which it has been observed to do, though at a distance of several ells from the disturbing cause. Such then are

the disturbing causes arising from iron, which the observer in vain endeavours to foresee, and which nevertheless displace the needle from its true position, and render all observation uncertain; by occasioning a difference of one degree or more. In like manner if the observation be taken at sea, on board a ship, the same causes are in operation to deflect the needle from its meridian. To this we may add, that if there be any magnet at a distance, as is generally the case with those who pursue observations of this kind, it will immediately withdraw the needle from the real degree of declination and bring it into another.

2. The needle may likewise be caused to deviate by a draught of air; for in case any wind be allowed to enter freely into the room, or to insinuate itself through chinks and other meatuses in the windows or walls, and it reaches the needle, we soon perceive the latter brought into a state of aberration, and removing to the next degree instead of keeping to the one which it ought to occupy. Indeed, often from the breath of the mouth, particularly when the observer is closely inspecting the quadrant, the degree, and minute of declination, some aura will find its way to the needle, and cause it to deviate so as to render questionable the accuracy of the observation on that day, or on that hour of the day.

3. There may likewise be numerous defects in the needle itself; for a needle ought to be so made as to be capable of maintaining upon its pivot every kind of equilibrium. If there be anything to destroy the equilibrium, then must this immediately affect the observation of the declination. If, for instance, the little cone which fits on to the pin is not in the true and central point of motion, the needle will incline immediately to the north or to the south, more or less upward or downward; or will decline more or less on one side than on the other; a declination which makes a difference in the observation of the minutes. If the pin be not as sharp as it ought to be, the motion of the declining needle becomes slower and more retarded. If the point of the pin, or the little cone upon it, should by length of time have contracted rust, so that its original velocity and freeness of motion be retarded, it will in this case decline with a difference of several minutes, or it may be a whole degree, instead of keeping to its true meridian. In like manner if the

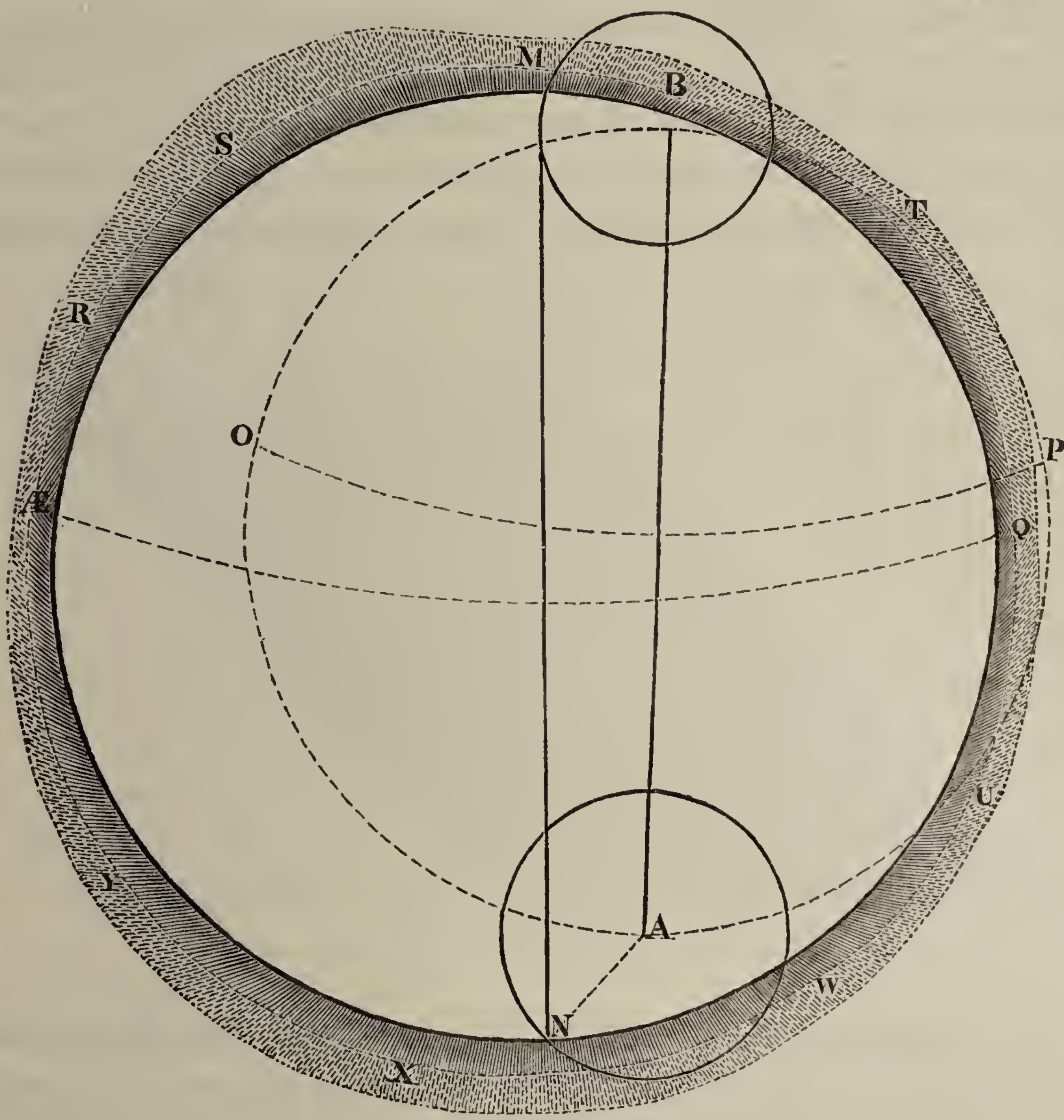
needle shall have begun to be tainted or corroded with rust, its vibration and inclination immediately become slower; or its motion is more difficult because the motive force is weaker. Many other are the causes which might be assigned, and which operate in impeding the motion of the needle; the recital of all which would be tedious.

4. If the plane upon which the box is placed and with which the observations are taken, is not perfectly horizontal, but inclines in any direction, particularly toward the east or west; then, although the needle, suspended on the pin and freely vibrating, endeavours to keep to the horizon, yet the plane of the box inclining to the left or right, renders the observation fallacious at least to the extent of some minutes. The eye of the examiner looking in a straight line from the rose of the needle, to the degree and minute of the quadrant, passes on to the degree or minute of the higher plane; and thus assumes as genuine what is only a fallacy. Hence if we move the box from this place to another, we shall find the needle ceasing to point to the same minute as it did in its first locality; and this both from the cause we have specified, as also from others; to say nothing of the quadrant not being divided into degrees and minutes as accurately as it ought, or of the sides of the instrument not being perfectly parallel with the line running east and west, or north and south in the quadrant.

5. We may add likewise, that the observation is rendered doubtful if the needle be too heavy, or if its magnetic force be too feeble; for hence will arise a slower motion and vibration, as also one over the proximate degree. Too sluggish to move farther it becomes quiescent, and through indolence stops short of its proper position. This is particularly the case in northern regions, where the needle does not tend so strongly to its true magnetic meridian as in places nearer to the equator. The reason is as follows; the particles of the magnetic element lie near the magnetic equator in a horizontal line, one particle there being connected with another in a horizontal direction. But nearer to the magnetic pole the particles change from a horizontal position, to one gradually more oblique; till near the pole they become perpendicular. For when the needle or the magnet is kept in its declinatory position by the magnetic

element (an element which operates upon the sphere of the magnet or needle, and directs it into its polar situation), and when the particles of the element are more erect, they cannot operate so strongly upon the sphere of the magnet or needle as when the same element maintained a horizontal position. In Fig. 84, let BOAP be the earth; B and A the two poles of the earth; OP its equator; M the north magnetic pole; N the south pole; ÆQ their equator; MÆNQ the earth; but the circle passes through each magnetic pole. Near the pole M and N the particles of the element are erect, or are perpendicular to the horizon. But at a distance thence, as at T or S, they are in an oblique position; that is to say, oblique in regard to the earth; and this obliquity is the same with the magnetic inclination. Near the equator in ÆQ, the particles of the same element

Fig. 84.*

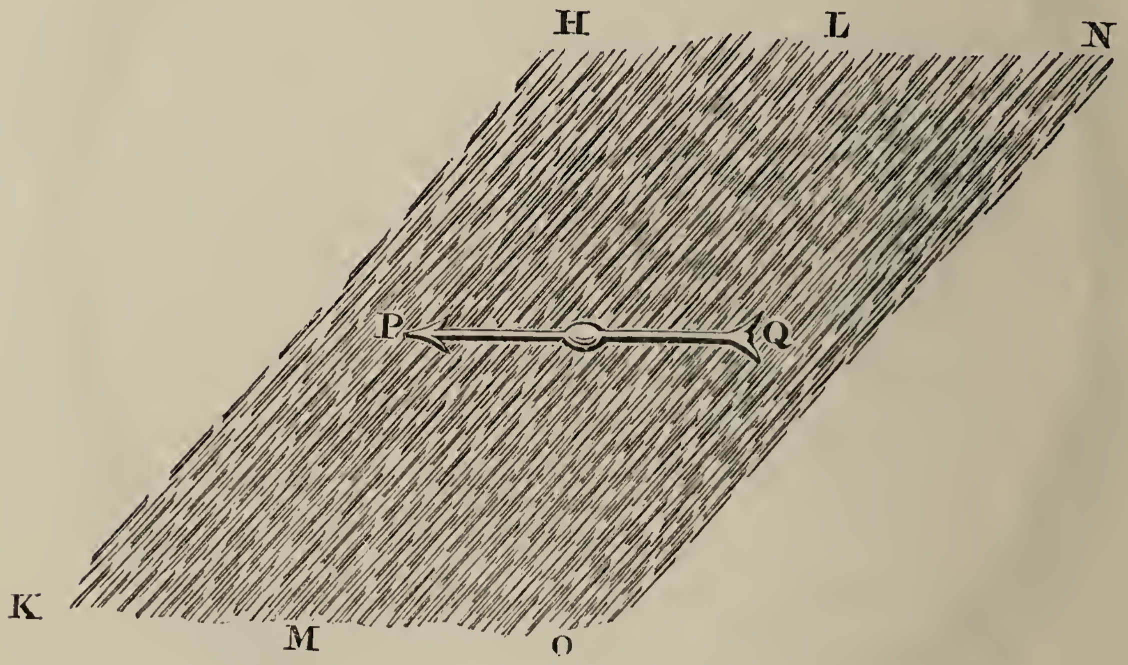


---

* In the original, plate XVIII., fig. 1.

lie horizontally; whence again they gradually become erect toward the other pole in N, and so on. The obliquity of this element is well seen in the inclination. When therefore the magnet or needle in its declination is urged by the situation of the particles of the magnetic element, then the needle evidently receives a direction in the element according with the position of the particles. If the situation be parallel, as in Fig. 82 (p. 68), where all the particles of the element lying horizontally regard both poles, the same needle is firmly detained in that position; for the current of the particles acts directly upon the sphere of the needle; but if the particles of the element are in an oblique position, as in Fig. 85, then the particles act obliquely upon the sphere of the needle PQ, and urge it further downwards rather than in the polar direction; and the more obliquely, so much the more feebly do they urge the needle toward its meridian. For the force pertaining to the needle is twofold; one urging it downwards, another horizontally, or in a polar direction. When the particles are more erect, then the force urging the needle downwards, or into an inclinatory position, is stronger than the one which urges it toward the horizon, or into a declinatory position. Near the pole itself, or some degrees distant, there can exist no declinatory directive force. This is the reason that the declinatory needle is urged with more feebleness toward

Fig. 85.*



---

* In the original, plate XVIII., fig. 3.

the magnetic meridian, in the northern and southern shores, than in the equinoctial regions; and that in case there is the slightest obstacle or cause of retardation, it deviates with the more facility from the true degree of declination, so as to prevent the various momenta from being observed with exactness.

6. With respect to the observation of the meridian of the place, though it ought to be perfectly exact, even the most accurate mathematicians are frequently in error. How necessary it is to be precise in taking the true meridian of a place, is perfectly well known. If the cusp or needle which is elevated for this purpose be not sufficiently pointed, or not poised on a perpendicular pin: if the aperture (for it is in this manner the observation is generally made) be not exactly perpendicular to the horizon; if the plane, in which the line of the meridian is to be drawn, decline in the least from the horizon, or be otherwise unequal; immediately an error insinuates itself unconsciously to the observer, and a meridian is obtained different from the true one by a distance of one or two degrees. So that if we wish to observe the declination in accordance with this meridian, the same error which is to be found in the meridian will carry itself into the declination; whence likewise the declination will be erroneous. Various may be the reasons for which a meridian once found and marked down, may not be the true one for the following years. The observatory itself may have contracted chinks; may have become slightly elevated, or have slightly sunk; in which case the meridian at first taken may be wrong by several minutes.

7. The declination likewise will be wrong, unless the altitude of the pole be observed as exactly as possible; for if the altitude be assumed as less or greater than it is, and if the declination be determined in conformity with the observation taken at that altitude, the real declination at such a latitude must be different from the one assigned. The exact observation of the latitude in places nearer the pole is most highly necessary; where at every different degree of latitude exists a considerable difference in the declination. As for instance, in the present day at the degrees 50, 60, 70, 80 of longitude west of London, and at an altitude of the pole of 50 or 60 degrees, as likewise at the south pole at the same latitude, at 100, 110, 120,

130 and 140 degrees of longitude east of London, there exists at any one degree of latitude a very sensible difference in the declination. Consequently a small irregularity in the observation of the latitude immediately originates a wrong declination; which at the given latitude must be different from the one assigned. Mariners, and all who examine the altitudes of the pole in a rough manner with quadrants and their radii, may easily suppose a certain latitude to be 50 degrees; when nevertheless, if taken with instruments perfectly exact, it would be 49 or 51 or 52; so that we must not blindly and confidently take for granted all the observations of the latitudes which have been taken by navigators, and consequently the declination existing at that latitude. In those places where there are the most skilful mathematicians, and where there are at hand quadrants most exactly divided, the true latitude of the place may indeed be taken; but not so where there are less skilful observers, whose instruments also are not so exact; still less so where the plane upon which they stand, as on board a ship for instance, be unstable and fluctuating with every wave; and this too at the moment in which the latitude is taken; a process which it requires some interval of time to complete.

8. Longitudes also are determined wherever the magnetic declinations of the needle are given, both on land and at sea. The longitude itself is known principally by the course and velocity of the ship every hour, every day, and which are designated in the maps. But the longitude on land frequently baffles the most experienced mathematician; therefore what must be the case at sea! Even now the longitudes of places are not sufficiently known to the world; as for instance, of those upon the shores and coasts of Africa, Asia, and America; although they have been taken by mariners and captains of vessels, who have either measured their course in the foregoing manner according to the longitude [*secundum longum*], or by the times of the eclipses, which, compared with the moments in which they occur in other places, have enabled them in some measure to supply the longitude; a calculation which may be true, but only in so far as the moments in which the eclipses occur have been observed with correctness by persons otherwise unskilful. But at sea, where conjecture only determines all the limits of the lon-

gitude, the degrees are assumed as 10 or 20 nearer the first meridian, or more distant thence, than is true. Since therefore the knowledge of the longitude is still so uncertain, and yet nevertheless a longitude is determined, and also a declination of the needle at the longitude thus determined, it follows that where there is error in the longitude, there is error in the declination; which at the given longitude must be different, and at the given degree of longitude must be greater or less by a difference often of several degrees; even as much as 3, 4, 5, 6 or 7. The point of chief importance, however, is from the given observation to learn the progress of the declinations when travelling west and east, or north and south. For the declinations observed in our course may either coincide or differ by several degrees. We must not therefore so far trust to the experiments of navigators as to assume them as the basis of our calculations, and to found upon them our theory of magnetic declination. If there be a difference of 1, 2, or 3 degrees, we are not therefore to conclude that the method of calculation is itself erroneous, or not theoretically true. These subjects however will be better understood in the sequel.

9. The observations of the declination which are taken at sea, where the ship is tossed about by the wind and waves, and when the feet, arms, and eyes of the observer are therefore in a state of constant motion, as also the instruments and compass itself rendered fluctuating and uncertain in their operations; it is no wonder that some difference of minutes, and perhaps of degrees, may be occasioned; particularly when we consider, that on the most fixed and stable ground, even where the observers are skilful, an error of one degree often insinuates itself; as may be concluded from the numerous experiments of those who have observed at one hour of the day a different declination from that which they observed at another; nay, a different declination on one day from that which was observed on the following; although the declination of the needle is very constant, and obeys as constantly as possible its first mobile or magnetic element; changing its position with the change of the times; the declination being increased or diminished according to causes which exist in the change of the situation of the particles in the element itself. This change cannot be made sensible

every hour or every day, but is nevertheless an imperfection in the obervation; which consequently becomes uncertain and diverse at different times for the reasons above mentioned; and often escapes the sagacity of the mathematician himself. Many are the proofs of the variations which occur on the same day, arising solely from the observer himself, and from the causes above mentioned; and which are adduced by Muschenbroek in his Treatise, page 15, &c. His words are as follow.

"I have above intimated, that not only every year but also every month and every day the declination is different; as is evident from the observations made by father Guy Tachart in the year 1682. For when in the presence of the King of Siam, in the city of Louvo belonging to that kingdom, he was attending to the needle, he found that one day it had declined toward the west 16 minutes; the second day 31 minutes; the third day 35 minutes; the fourth day 38 minutes. On other days of the same year, and between which there was no great interval, he observed a deviation of 28 minutes; on another day a deviation of 33 minutes; and on a third day a deviation of 21 minutes. See his *Itinerary*, pages 224, 225. These seven observations were made beyond a doubt within the space of a month; and from these it is evident that the needle exhibits some variation every day. Whether any one else before this father has ever observed this daily mutation, I know not; but I am able to confirm it from my own experience, for

		The Needle declined.	
		Deg.	Min.
1728.	8 March..	13	20
	8 April ..	13	15
	10	13	19
	11	13	20
	12	13	20
	15	13	14
	16	13	15
1728.	17 April ..	13	15
	18	13	15
	19	13	15
	20	13	18
	21	13	15
	22	13	15
	23	13	15

But Graham, the celebrated mechanician of London, has attended to this circumstance very minutely, and has instituted many observations which he has inserted in the English *Philosophical Transactions*, No. 383, page 96, A.D. 1724; which as being the best that have yet been made, I will here subjoin, since they entirely confirm and illustrate both our own observations and those of Tachart, which at first sight might appear to be dubious.

He first constructed a most accurate needle, which was of considerable length, well rubbed upon a most powerful magnet, and inclosed in a capsule of copper which contained the arc of a circle in which were marked the degrees and minutes. This capsule was placed upon the meridian line, so that the declination of the needle toward the west might be the better observed. He then remarked the following results :—

Declination of the Needle in March, 1722, was				Another Needle within a capsule of wood.	
Deg.	Min.	Hours.	Min.	Deg.	Min,
14	30—	3	0	14	25+
14	20	3	15	14	20
14	15+	4	0	14	10
14	15	5	45	14	10
14	0	5	57	14	0—
14	0—	6	8	13	55
13	50	6	15	13	40
14	20	6	38	14	15+
14	20	4	15	14	15
14	25	5	0	14	20
14	25	5	30	14	20
14	0+	6	48	14	0
14	0	6	54	14	0—
14	5	7	5	14	0+
14	10	7	15	14	5
14	0+	12	0	14	0+

The sign + denotes something more.

The sign — denotes something less.

From these experiments we collect that the declination of the needle varies nearly every hour; nay, almost every minute; as some of the observations demonstrate.

2. Two needles rubbed against the same magnet have a different declination; one declining in a copper capsule 14° 30″, the other in a wooden one 14° 25′.

3. It is evident that the declination is changed simultaneously in every needle, but not equally; for at one time it is greater in one needle; at another time in another. Both of the first observations with the needle in the copper capsule prove, that the variation = 10′; when in wood the difference of the variation = 5′. But the third variation in the copper capsule differs from the second only 5′, while the third in the wooden capsule differs from the second 10′.

4. But within the space of 3 ho. 8′, the variation in each needle = 30′.

I wish the observer had at the same time attended to the winds and their changes; possibly he might have discovered something affecting the observation under these circumstances.

We shall here however annex other observations made on the following days; from which it is evident that these mutations in the needle are happening always and daily; nay, even every hour.

Declination.	Deg.	Min.	Hours.	Min.
March	14	10	9	30
9	14	10+	10	0
	14	10	10	15
	14	10+	10	30
	14	15	11	0
	14	0	8	15
	14	0	11	50
March	14	10+	10	0
10	14	15	11	0
	14	15	12	0
March	14	15+	12	45
10	14	15+	2	0
	14	15	3	30
	14	15+	4	0
	14	15−	5	30
	14	10	6	0
	14	0	6	15
	14	0	6	30
	14+	0	7	30
	14	5	7	45
	14+	0	12	0

Many more observations may be met with in the fore-mentioned *Philosophical Transactions.* The observer remarks that he had made more than a thousand observations in the same place, with the same needles, all of which were similar one to another. These experiments are obviously contrary to those which Cabæus has mentioned in book i., chap. xvi.; where he rashly affirms that in the same place the declination is always the same.

Muller, in his *Colleg. Experiment.*, page 237, adduces an observation of his brother, who remarked, that at the tops of mountains the needle declines 10, 20, 50, and even 90 degrees more than at their bases; and that this obtains on the mountains of Bohemia, and near the ancient Brisacus; he also says that it obtains in the mountains of Saxony. This paradox in mountainous regions is worthy of further examination, and requires further confirmation; in which case much additional light might be thrown upon the doctrine of magnetism; for the iron which many of the mountains contain, may originate considerable varieties in these and similar observations."

Thus far Muschenbroek.

What then, I would ask, can afford ground for believing, that the needle or its declination is within a few minutes of time liable to so many mutations? when after all it may possibly be an error in the observation; a contingency which I consider to be unquestionable. The very experiments of Graham demonstrate that two needles rubbed against the same magnet have a different declination; one declining in a copper capsule 14° 30′; the other in a wooden capsule 14° 25′. In like manner within the space of 3 hours and 8 minutes, the variation in each needle was 30′; a difference which is scarcely to be found within 3 or 4 years; nor can any halitus, pregnant with iron effluvia and wafted by the wind, be the cause of such a variation.

I am apprehensive, that the same contingencies, if I might venture so to speak, occurred to the Parisian observers; who remarked the same and similar declinations in the years 1720, 1721, 1722, 1723, 1724, 1725; viz., a declination of 13° without any annual increase. Sometimes indeed they observed a retrogradation; as in the years 1712, 1713; as also in the years 1714, 1715; although in the vast and permanent system formed by the magnetic element (which surrounds our globe and constitutes both the solar and planetary vortices, and which in succession of time, from natural causes, and by an undeviating law of connexion, changes its situation and produces always a different declination), there cannot exist changes so light and surreptitious as those we have mentioned. If therefore such great men as we have mentioned, who are not at a loss for proper opportunities, can be mistaken in their experiments; what are we to say of the common class of observers, of inferior and more unlearned note, who precipitately make their experiments and publish them without having taken the due precautions?

Before proceeding to calculations, I will premise the observations of some declinations made by various authors at different times and in different places.

---

* In the ensuing tables, the initial O, which frequently occurs, will stand in the Latin either for *oriens* or *occidens*, and as the translator has not been always able to determine which it means, he has allowed it to remain, that the more experienced reader may decide for himself. He has also added notes of interrogation after the names of some places concerning which he was in doubt.—*(Tr.)*

I.

A general Table of Declinations at Sea, taken from nautical observations made by Portuguese, English, and Dutch mathematicians, as well as by others, members of the Society of Jesus. From Athanasius Kircher, for the years* 1500 *to* 1600.

	Declination. East. Deg.	Declination. East. Min.	Latitude. North. Deg.	Latitude. North. Min.
From the Rock of Lisbon, 50 leagues towards N.W.	6	5	39	10
As given by others	7	0	39	10
	10	0	39	10
From Lisbon to the Cape Verd Islands	8	30	39	10
From Cape St. Vincent three or four leagues towards W.	5	38	39	10
From St. Mary, one of the Azores, 9 leagues O.S.	2	20	39	10
At Fayal, and thence to Terceira.	3	45	39	45
From Terceira towards Lisbon	7	30	39	45
From the Island of Flores towards the west 40 leagues	8	30	39	10
And from Cape Blanco 300 leagues	4	0	39	10
From the Island of Flores towards the east 70 or 80 leagues	0	0	39	10
From the same island towards W. 30 leagues	0	0	39	10
	West.			
In passing the meridian of the Islands of Flores and Corvo	1	0	39	10
From the Island of Flores 100 or 200 leagues towards the west	2	0	39	10
	1	0	39	10
In sight of the Island of Flores S.O.	5	37	39	10
From the Island of Flores, W. 230 leagues	3	30	39	19
Near Pico	1	30	39	19
From the Canaries 20 leagues	1	0	19	0
	East.			
At the Canaries	5	37	32	0
From the Great Canary Island towards the north	4	37	32	0
From the Islands of Seluages [?]	5	37	31	0
At the S.W. side of the Great Canary Island	5	20	28	0
From the Canary Islands 230 leagues	0	0	20	0
From observations taken while coming from the West Indies, shortly before reaching the Canaries	0	0	33	0

---

* *Magnes; sive de Arte Magneticâ*, p. 387, seqq.

				East.		North.	
				Deg.	Min.	Deg.	Min.
And shortly after passing them				5	37	27	20
From Palma towards Cape Blanco				3	0	24	0
From Cape Blanco nearly 2 leagues				2	40	21	0
From Cape Blanco....	W. S.W.	20	Leagues	2	40	20	25
	W.	63		5	37	19	20
	W.	90		5	0	18	35
	W.	100		6	0	18	35
	O.	436		7	30	17	42
	O.	470		7	30	11	57
	O.	476		7	36	16	35
	O.	535		7	30	10	59
	O.	595		5	0	10	15
	O.	640		4	3	10	0
	O.	700		1	3	9	20
At Cape Verd				4	0	14	54
From the Cape Verd Islands 300 leagues towards W.				5	38	14	0
At the Islands of St. Jago and St. Nicholas				2	38	14	0
From Cape Verd 100 or 120 leagues				3	45	14	0
From the Islands of Bravo and Jago 12 leagues towards W. N.W.				4	30	14	0
From Mayo 46 leagues towards S.E.				5	8	14	20
According to other observations				3	30	14	0
From Cape Verd on the passage towards the East Indies				4	0	6	0
According to observations made in passing the Equinoctial				5	0	0	0
At the Island of Trinidad				0	0	9	46
From this island 90 leagues towards O.W.				1	0	9	46
According to other observations				2	0	9	46
				West.			
At Margaritta, and at St. Cruz near St. Juan de Porto Rico				0	0	23	0
From St. Juan de Porto Rico, N. N.W.				8	0	14	20
In the meridian of the Island of Barbadoes, 15 leagues from Martinique				1	0	14	20
At the Island of Guadaloupe				1	0	15	18
At Cursands [?] and West India Islands				4	0	12	13
At the mouth of the river Hacha [?]				7	36	11	20
Off the river Mayo				15	0	31	0
Near Cape Corrientes in the Island of Cuba				3	0	9	30
At Cape St. Anthony in the Island of Cuba				13	0	22	0

	West.		North.	
	Deg.	Min.	Deg.	Min.
At Cape Cameron	5	0	25	40
At Cape Florida	3	0	25	30
Towards the north of Cape Florida	13	0	28	0
Near the coast of America	11	0	35	30
From the Bermudas, 140 leagues towards the west	10	3	30	35
From Cape Race, S. S.W.	6	30	39	40
	East.			
From Sierra Leone, W.S.	6	0	7	0
			South.	
From Cape Sierra Leone for 220 leagues towards the west, it constantly increases from one degree to	6	45	—	—
At Cape St. Augustin	7	0	7	16
From Cape St. Augustin 100 leagues	11	6	8	30
At the Island of Fernando da Noronha, near Brazil	3	45	2	20
In the meridian of Trinidad, near Brazil	11	10	8	0
Between the Islands of Trinidad and Ascension	12	10	20	30
At the Island of Ascension	10	0	20	0
In the meridian of Trinidad, towards O.	14	53	27	0
Between the Islands of Trinidad and Tristan d'Acunha	18 19	0 0	36 36	20 20
From the shore of Brazil, 14 leagues towards the east	12	30	19	30
From the shore of Brazil 150 leagues	10	0	18	0
At Cape St. Vincent in Brazil	12	0	—	—
From the shore of Brazil 100 or 120 leagues	8 7	30 30	17 18	0 0
From the Island of Ascension 20 or 30 leagues towards the east, and at the rocks of Penedo di St. Pietro	5	30	—	—
Between the Islands of Ascension and St. Helena	7	30	0	0
At the Island of St. Helena the declination varies 2, 3, 4, 5, 7, 9 degrees. At the Islands of Martin Vas	13	0	19	0
From these islands towards the north 30 leagues	18	30	35	25
Beyond the Islands of Tristan d'Acunha 70 leagues	16	53	33	0
From the Islands of Tristan d'Acunha, to the west	17	52	34	35
At the Islands of Tristan d'Acunha	19	0	—	—

	East.		South.	
	Deg.	Min.	Deg.	Min.
On the passage from that island off the Cape of Good Hope	14	0	23	25
Near Cape Frio	13	0	23	30
According to other observations	12	0	23	30
From Cape Frio towards the west off the coast of Africa	17	0	17	19
	18	0	17	19
From Cape Frio 125 leagues towards the west	11	8	18	20
At Port Desire	5	0	47	40
At the entrance to the Straits of Magellan	5	30	53	15
In the Straits	5	0	54	27
From the Cape of Good Hope 900 leagues W.N.	15	52	26	50
At the Bay of Soldan (Sudanna Bay)	0	0	33	55
	1	30	33	20
At the Cape of Good Hope	0	15	36	15
	1	30	35	10
	2	0	35	0
	West.			
From the Cape of Good Hope, 36 leagues S.W. S.	4	10	35	25
And 28 leagues thence	3	50	35	30
From the same Cape towards S.	3	45	35	16
And towards W. 40 or 50 leagues	3	0	35	40
At Cape de Agulhas, near the Cape of Good Hope	0	0	35	19
And thence towards the east 80 leagues	0	0	35	10
From Cape Aquillas towards N.O., in sight of Terra Nova	3	47	34	20
At Cape Corrientes beyond the Cape of Good Hope	7	30	25	0
	11	0	25	40
			North.	
At the Primera Islands, off Mozambique	15	0	18	0
In the Island of Mozambique	12	0	14	45
At the Island of Zanzibar	7	46	8	10
	10	0	7	30
At the Island of Almirante, near the Equinoctial	13	0	0	0
Near Cape Guardafui	8	15	13	15
At the mouth of the Red Sea	5	15	12	15
At Port Igidid [?]	0	40	22	0
At Xuarit [?]	0	15	0	0
	East.			
At the Bay of Sidon	2	35	33	30
	West.			
At Goa in India	17	0	15	20

	West.		North.	
	Deg.	Min.	Deg.	Min.
According to other observations	16	40	15	20
			South.	
At the Comora Islands	13	0	12	31
In the Island of Madagascar, near the Bay of St. Augustin	15	0	15	20
At Cape Romain, in the Island of Madagascar	8	30	26	0
From the same Cape, 110 leagues W. S.W.	14	14	46	34
In the Bay of Antongil, in the Island of Madagascar	25	0	17	0
According to other observations	20	0	0	0
In the Bay of Tassarin [?]	5	30	0	0
Western coast of the Island of Saya de Malha	15	0	11	30
At the Island of Pagapez	23	11	10	0
At Grace Island, 36 leagues W. S.W.	24	11	9	20
At the Arenaria [?] of India	8	30	30	0
At the Island of Didaci Roix	21	20	20	0
At the Islands of Los Romeros, 68 leagues S.W.	24	15	31	0
From the same islands 110 leagues	21	20	30	40
At the Arenaria [?] of Adu and Candu	19	30	6	0
At the Island of Didaci Gratiosi	24	0	9	0
From this island towards W. 20 leagues	22	0	7	30
At the Island of Didaci Roderici	20	0	35	0
	East.		North.	
From the same island, S. and S.O.	25	0	36	0
	24	0	36	0
	25	0	36	0
At the Maldive Islands	17	0	0	0
At Cochin in the East Indies	13	0	9	40
From Cochin towards the Maldive Islands, S.S.W.	—	—	8	0
At 8 and 10 degrees, south latitude	16	52	10	0
At Zeilah	15	30	9	0
At the Island of Pulo Batu [?], according to some 4°, according to others	2	0	4	0
At Acheen in Sumatra	8	0		
			South.	
On the west side of Sumatra in the Island of Priamaria	5	40	0	21
Near Bantam in Java	5	0	—	—
	4	30	7	0
At Madeira	2	30	6	36
In Java Major	0	0	7	30

	East.		North.	
	Deg.	Min.	Deg.	Min.
In the Philippine Islands the declination is various				
At Macao in China	1	½	22	30
At the mouth of the Canton River	0	0	25	12
In Japan	8	30	40	30
In the Salomon Islands	4	0	—	—
From the Island of Ferdinand, 200 leagues in the Mari del Zur	0	0	—	—
In Davis' Straits the greatest declination has been observed by the Dutch	50	0	62	50

Observations made in the Northern Regions by the English and Dutch.

	West.		North.	
	Deg.	Min.	Deg.	Min.
At Eishaven in Nova Zembla	22	30	76	0
On the western coast of Nova Zembla	26	0	76	0
From Nova Zembla, 20 leagues towards the west	31	0	73	0
At Cross Island, near Nova Zembla	17	0	73	0
At the Nova Terra of the Dutch, commonly called Nielandt	16	0	81	0
Island of Vaigatz	7	0	71	0
James Island	7	30	70	40
At the Straits near Pechora	3	30	69	10
At the North Cape	1	0	71	30
Midway between Friesland and Labrador	28	0	62	0
	East.			
According to observations made in a voyage along the English coast, from Yarmouth towards the north	12	40	55	14
On a voyage from London towards Russia, at one time to the west, 3, 7, 8 deg.; at another time, to the east	4	0	65	40
	5	10	64	30
	3	0	66	30
	West.			
At Antwerp	9	0	51	0
At Amsterdam	9	30	52	20
At London	11	30	51	32
At Portland	10	0	51	32
Churchyard of St. John, on the coast of Cornwall	8	0	50	30

	West.		North.	
	Deg.	Min.	Deg.	Min.
At Youghal in Ireland	10	0	49	55
From Bellisle towards the west 350 leagues	1	0	52	10
From Scilly, W. N.W. 235 leagues	0	0	45	0
From Scilly, W. N.W. 514 leagues	10	0	60	0
Thence, N.W. N.	16	0	63	30
And thence again N.W.	22	0	66	0
From this place, N.W.	28	0	73	0
From this, W.W. 40 leagues	33	0	73	0
At Cumberland Island	30	0	64	0
At Cape Sanderson	28	0	72	12
At Cape Race, in Newfoundland	8	0	47	0
From Cape Race, S.W.	2	52	34	35
	35	30	5	37
	East.			
At Cape Finisterre	8	30	39	40
Coast of Virginia, 36 deg.	12	0	0	0
Island of Martin, one of the Camertan Islands, 21 deg.	0	0	21	0

II.

A Table, shewing the Longitudes and Latitudes of various places, together with the Declination of the Magnet; derived chiefly from the observations made by John Telier, in his voyage to the East Indies, by Athanasius Kircher.

Longitude.		Latitude.			Declin. East.	
Deg.	Min.	Deg.	Min.		Deg.	Min.
0	17	16	50	North	2	40
0	48	45	46		5	15
1	0	17	33	South	9	30
1	3	20	11		11	27
2	0	22	56		13	0
2	32	9	50		6	40
3	6	7	0		5	45
3	20	25	34		14	0
3	40	4	50	North	3	50
4	55	33	44	South	12	34
5	18	40	0		7	30
5	22	1	40		5	20
5	28	25	11	South	15	20
5	39	3	14		7	34
5	45	2	30		7	12
5	51	1	30		6	0
6	0	1	6		5	0
6	0	4	27		7	25
6	6	9	36	North	3	10
6	10	14	30		2	45
6	10	29	45		6	0
6	15	27	22	South	13	30
6	40	14	50		11	0
6	40	2	54	North	4	0

Longitude.		Latitude.			Declin. East.	
Deg.	Min.	Deg.	Min.		Deg.	Min.
6	50	19	24	North	3	33
7	9	0	20		4	15
7	35	0	40	South	4	40
7	39	21	8	North	4	47
7	55	33	44	South	13	20
8	0	23	30		13	0
8	12	52	8	North	11	0
8	15	2	26		4	10
8	30	38	55		10	0
9	2	29	2	South	13	15
9	40	6	16	North	2	15
9	40	7	19		2	30
9	50	29	46		6	39
10	10	4	10	South	5	30
10	10	7	39	North	2	35
10	13	31	42		6	16
10	35	3	19		3	30
10	56	35	40		7	10
11	10	8	15		2	40
11	30	46	50		8	0
11	50	30	42	South	12	30
12	15	7	0		6	0
12	32	49	9	North	8	50
13	52	8	4	South	6	15
15	10	50	10	North	9	0
16	15	31	20	South	11	25
16	18	31	0		12	0
17	0	55	0	North	12	40
18	6	51	24		11	30
20	18	33	31	South	10	15
20	26	15	0		6	0
21	55	16	0		5	30
22	42	16	24		5	20
23	0	50	10	North	6	30
23	45	17	20	South	5	15
25	15	18	20		5	10
27	18	34	16		8	30
27	50	20	0		5	0
31	14	34	2		5	0
33	40	34	2		3	0
35	0	34	9		2	20

Longitude.		Latitude.			Declin. East.	
Deg.	Min.	Deg.	Min.		Deg.	Min.
36	16	34	3	South	1	40
36	20	26	15		2	0
39	30	28	26		0	45
39	46	34	27		0	25
41	10	34	13		0	5
347	25	27	36	North	4	0
348	55	36	0		4	0
349	51	35	20		3	40
350	0	35	0		3	50
351	0	8	30	South	3	10
352	20	37	0	North	3	20
353	7	22	25		3	30
356	17	37	40		3	45
356	22	14	20		3	0
356	30	19	20		3	15
356	42	32	36		3	50
356	56	37	25		3	30
357	25	39	30		4	0
357	35	18	16		3	0
357	48	12	48		3	15
357	27	11	15		3	0
359	40	9	25		3	15
359	40	44	0		4	0
					West.	
42	7	34	0	South	1	40
43	16	34	16		—	16
43	53	32	0		—	30
44	32	34	4		—	46
44	44	32	45		1	40
45	37	33	42		1	15
46	16	34	0		1	45
46	36	34	0		1	45
46	40	35	0		2	0
47	19	36	16		3	20
47	30	71	10		2	0
48	54	35	20	North	4	30
49	45	35	50	South	4	15
50	50	36	15		5	45
51	12	37	35		6	30
51	49	35	6		6	30

Longitude.		Latitude.			Declin. West.	
Deg.	Min.	Deg.	Min.		Deg.	Min.
52	15	37	0	South	7	0
53	2	36	0		8	20
53	15	33	30	North	8	0
53	28	34	0	South	8	5
54	15	35	21		9	0
57	27	35	15		11	0
58	42	33	45		13	0
60	10	36	0		13	0
61	40	33	15		15	0
61	40	36	48		14	30
64	13	37	0		16	0
64	18	27	42		15	0
65	20	32	20		16	30
65	24	25	44		15	10
65	37	17	44		12	30
66	6	24	50		15	20
66	20	19	20		13	7
66	24	32	47		16	0
66	40	14	50		11	0
67	13	24	5		15	40
67	15	29	0		15	30
67	20	20	39		13	30
67	27	16	6		12	50
67	47	21	50		14	0
68	20	34	0		18	30
69	11	25	4		15	39
69	36	28	0		17	10
69	52	5	0		14	5
69	56	34	40		19	4
71	20	28	0		16	0
71	40	11	30		15	0
72	23	5	12	North	11	0
74	28	34	5	South	22	50
75	9	31	0		21	0
76	52	2	0	North	14	45
77	33	31	0	South	22	30
78	16	32	20		23	0
78	54	31	0		22	50
79	5	3	48	North	15	40
80	39	31	50	South	23	30
81	45	32	0		23	15
81	54	6	0	North	16	30
83	57	30	50	South	25	22
84	22	14	20	North	17	0
84	25	13	45		18	0
84	30	73	20		25	0
85	53	10	20		17	0
86	16	12	0		18	0
86	25	13	45		18	30
86	36	30	10		24	50
87	0	69	30		24	30
87	2	30	0	South	24	0
88	32	13	18	North	19	40
91	32	12	45		20	38
92	1	26	24	South	24	20
92	30	26	53		22	0
93	18	12	45	North	20	30
93	35	26	20	South	21	48
93	48	25	15		23	30
94	0	75	35	North	33	0
94	15	25	42	South	21	50
94	57	13	6	North	20	10
95	0	19	20	South	22	0
95	15	24	37		21	0
95	50	23	43		20	40
96	39	13	22	North	19	0
96	40	23	32	South	23	0
98	14	13	42	North	18	0
98	44	22	50	South	22	0
98	50	19	27		17	40
100	33	14	10	North	16	30
101	5	16	18	South	16	20
101	50	20	56		19	30
102	35	15	25		15	20
102	38	15	0		14	35
103	12	14	10	North	16	0
104	20	19	56	South	17	30
105	0	15	30		15	10
106	0	13	9	North	15	30
106	20	19	56		16	36
106	38	13	33	South	13	0
108	25	11	27		11	40

Longitude.		Latitude.			Declin. West.	
Deg.	Min.	Deg.	Min.		Deg.	Min.
108	30	19	5	North	15	0
109	20	10	32	South	11	0
110	35	5	54	North	13	40
111	0	18	5	South	13	0
111	53	8	30		9	47
112	15	17	10		12	0
112	23	8	0		9	16
113	50	6	59		8	40
114	51	6	42		8	0
114	3	5	12	North	11	0
114	35	15	2	South	10	30
115	45	6	24		7	33
116	30	6	26		6	40
117	32	14	12		9	30
119	23	2	0	North	8	0
121	59	12	57	South	7	30
123	43	0	10		5	45
125	50	1	53	North	5	15
126	—	9	40	South	5	0
127	14	5	0	North	4	0
127	15	7	26	South	4	30
128	33	1	9	North	4	0
129	50	3	46	South	4	15
129	12	0	26		4	0
130	59	12	57		7	30
141	40	4	36	North	3	30
207	0	8	40	South	1	30
344	30	77	12	North	27	0
346	0	37	0		0	0

III.

A Table of Magnetic Declinations, observed by Mathematicians in various parts of Europe, at the solicitation of Kircher.

	Declination.			Latitude.	
	Deg.	Min.		Deg.	Min.
At Lisbon, from accounts collected by Chrysost. Gallus, Soc. Ies., and Christopher Burrus .	7	39		39	38
At Evora in Portugal, according to Martinus Martinius, S.I.	6	12		39	0
At Coimbra in Portugal, by the same..........	6	3		40	30
At Madrid, by Christoph. Burrus, S.I.........	5 (about)			40	45
At Paris, by F. Marinus Mersennus and Peter Bourdin, S.I.........................	31	0		48	40
At Tours in France, by Jacobus Grandamicus, S.I.	4	50		43	43
At Dole in Burgundy, by Vincent Leotaud, S.I.	5	14		46	48
At Besancon, by Kircher	5	0		47	15
At Lyons, by Kircher	4	30		45	10
At Tournon, by Anton. Laloure, S.I.	3	51	East.	45	16
At Avignon, by Francisco de Payen, Peter de St. Eligius, and Kircher	3	10		—	—
	4	0		43	42
	4	30		—	—
Montpellier, by Gulielm. Degner, S.I.........	3	30		43	30

	Declination East.		Latitude.	
	Deg.	Min.	Deg.	Min.
At Arles, by Kircher	3	30	43	38
At Marseilles, by Peter Gassendi	2	40	43	20
At Digne, by Peter Gassendi	2	40	43	0
At Aix, by Peter Gassendi	2	36	43	25
At Villa Franca, near Nyssa, by Kircher	2	26 West	43	30
At Leghorn, by F. Z. Francisco Niceron	5	0	42	30
At Genoa, by Martinus Martinius, S.I.	5	58	43	50
At Genoa, by Hieronymus Bardius	5	30	43	50
At Milan, by Carolus Moneta, S.I.	2	30	45	6
At Mantua, by Franciscus Jardinus	0	30	45	12
At Bologna, by D. I. Baptista Manzinus	3	0	44	16
At Ferrara, by Nicholas Cabæus, S.I.	5	50	44	10
At Parma, by Josephus Blancanus, S.I.	6	0	44	30
At Venice, by various observers	5	0	45	0
At Rome, by P. I. Baptista Giattino, S.I.	3	(about)	—	—
At Rome, by P. I. Anton. Martinus, S.I.	2	50	—	—
At Rome, by D. Caspari Berti	3	(about)	41	56
At Rome, by Kircher	2	45	—	—
At Rome, by R. P. F. R. Franciscus Niceron	2	40	—	—
At Rome, by D. Fanciscus Perseus	3	(about)	—	—
At Florence, by P. F. R. Franciscus Niceron	3	30	43	40
At Loretto, by Kircher	4	0 West	44	10
At Bologna, by Carolus Antonius Manzinus	3	0	—	—
At Leghorn, by Niceron	5	0	44	30
At Naples, by P. I. Baptista Zupus, S.I.	0	30 West	41	0
Cape Palinuro, by Kircher	2	13	40	6
At Poala, by Kircher	2	30 West	39	50
At Tropia, by Kircher	2	40	38	32
At Messina, near Charybdis, by Kircher	0	0	38	50
At Malta, by D. Franciscus Jardinus	0	0	35	26
At Palermo, by Carolus de Vintimiglia and Fredericus Fontanerus	5	0	37	0
and Paulus Chiaranda, S.I.	7	0	37	0
On Etna, near the three Chestnut Trees, by Kircher	6	0	37	40
At Syracuse, by Kircher	6	(about)	37	15
At London, by William Gilbert	11	0	52	30
At Antwerp, according to various observers	8	30	51	48
At Louvain, by John Ciermans	9	0	51	32
At Ghent, by Gregory a St. Vincent, S.I.	1	40	51	30
At Amsterdam, by Iodocus Hondiu	9	30	51	38

	Declination West.		Latitude.	
	Deg.	Min.	Deg.	Min.
At Leyden, according to various observers	9	30	51	30
At Dort, according to Mersennus	2	(little more)	51	38
At Emmerich, by Iodocus Kedd, S.I.	5	52	50	49
At Triers, by Kircher	6	24	49	12
At Cologne, by Joh. Grothaus, S.I.	3	0	50	36
At Cologne, by Lubertus Middendorff, S.I.	1	½	—	—
At Munster in Westphalia, by Laurentius Mattenkloth, S.I.	5	48	51	46
At Paderborn, by Hubert Linz, S.I.	5	(about)	51	29
At Aschaffenburg, by P. I. Reinardus Zieglerus	6	20	50	8
At Mentz, by Henricus Marcellus, S.I.	6	7	5	30
At Fuld, by Kircher	4	30	50	38
At Wirtzburg, by Kircher	5	15	49	57
At Nuremberg, by George Hartmann	8	(given variously)	49	30
At Heidelberg, by Kircher	6	10	49	10
At Innspruck, in the Tyrol, by Baptista Cysato, S.I.	2	0	46	55
At Ingoldstadt, by Jacobus Viva, S.I., and Gulielminus Gumpenberg, S.I.	4	30	48	40
At Ebersberg in Bavaria, by Michaelis Staudacher, S.I.	4	26	48	37
At Fribourg in Brisgow, by George Schenberger, S.I.	4	30	48	46
At Prague in Bohemia, by Theodorus Moretus, S.I.	5	30	50	20
At Olmutz in Moravia, by Conrad Balthazar, S.I.	2	30	50	24
At Nyssa in Cilicia, by Christ. Scheiner, S.I.	—	—		
At Vienna in Austria, by Andreas Cobavius, S.I.	0	0	48	20
At Gracz in Styria, by Jacobus Durandus, S.I.	2	0	48	10
At Wilna in Lithuania, by Osvaldus Krugerus, S.I.	3	40	53	0
At Nisvis in Lithuania, by Osvaldus Krugerus, S.I.	3	40	53	0
At Orsa in Lithuania, by the same	3	40	53	0
At Constantinople, by various observers	0	0	43	5
At Aleppo in Syria, by Joh. Amicus, S.I., and Amatus Chesaud, S.I.	3	0	37	26
At Alexandria in Egypt, by John Graves	5	45	30	0
At Goa in India, by Joh. Uremannus, S.I.	17	(about)	16	0
In Narsingah in India, by Petrus Rubinus, S.I.	12	0	18	30
At Canton in China, by Joh. Uremannus	0	0	33	0
At Macao in China, by Joh. Uremannus	1	30	22	0

IV.

Declinations observed by M. Martinius, in the year (as I think) 1638*; and given by Kircher in his work, "De Arte Mag."*

	Declinat. East. Deg.	Min.
In the Port of Lisbon	7	39
Thence to the western coast of Madeira, gradually decreasing to	5	49
In latitude 28 deg. 25 min.	6	3
To the south of Palma 20 leagues	7	20
The like all the way to Cape Verd.		
To the west of Cape Verd 46 leagues	7	30
In Guinea, under 7 deg. lat.	8	0
From Cape Verd, 220 leagues to the west, at a latitude of 18 degrees	5	0
But the needle is stationary at almost the same latitude 340 leagues from Cape Verd	0	0
From about 15 deg. latitude to about 18, the needle is stationary, that is to say, for 150 leagues, and still more so from the Cape Verd Islands	0	0
From the 28th to the 30th deg. of latitude, the needle declines to the western coast of the Island of Flores, which is one of the Azores; from this towards the west, 40 leagues	1	12

V.

The Declinations of the Magnet at the principal places in the Mediterranean; taken also from Kircher, for the year 1638.

	Declination. Deg.	Min.
In the Stœchades Islands (Les Isles d'Hyeres)	5	0
Island of St. Honorè	4	10
At Genoa	5	0
At Cape di Corso, in Corsica	7	30
At Porto Longone, Island of Elba	5	0
Cosmopolitan shore, ditto	8	0
In Porto Ferrajo, ditto	20	0
In Ænaria, or Procita	1	15

	Declination.	
	Deg.	Min.
In the Lipari Islands, near Volcano	2	19
At Messina, near Pharos at Charybdis	0	10
At Malta	0	0
Near the Peloponesus	0	0
Off the eastern coast of Crete	15	0
At Alexandria, in Egypt	5	45
In the Archipelago, various	—	—
At Constantinople	0	0

VI.

A Table of various Declinations for various years, inserted in the Acta Lipsiensia for August, 1684.

	Longitude from London.		Latitude.			Declination.	
Names of Places.	Deg.	Min.	Deg.	Min.	Year.	Deg.	Min.
At London	0	0	51	32 N.	1580	11	15 East
	—	—	—	—	1622	6	0
	—	—	—	—	1634	4	5
	—	—	—	—	1672	2	30 West
	—	—	—	—	1683	4	30
Paris	2	25 East	48	51	1640	3	0 East
	—	—	—	—	1666	0	0
	—	—	—	—	1681	2	30 West
Uraniborg	13	0	55	54	1672	2	35
Copenhagen	12	53	55	41	1649	1	30 East
	—	—	—	—	1672	3	35 West
Dantzic	19	0	54	32	1679	7	0
Montpellier	4	0	43	37	1674	1	10
Brest	4	25 West	48	23	1680	1	45
Rome	13	0 East	41	50	1681	5	0
Bayonne	1	20 West	43	30	1680	1	20
Hudson's Bay	79	40	51	0	1668	19	15
Hudson's Straits	57	0	61	0	1668	29	30
In Baffin's Bay, Sir T. Smith's Sound	80	0	78	0	1616	57	0
At Sea	50	0	38	40	1682	7	30
	31	30	43	50	1682	5	30
	42	0	21	0	1678	0	40 East
Cape St. Augustin, Brazil	35	30	8	0 S.	1670	5	30

	Longitude from London.		Latitude.			Declination.	
Names of Places.	Deg.	Min.	Deg.	Min.	Year.	Deg.	Min.
Cape Frio	41	10 West	22	40 S.	1670	12	10 East
At Sea, off the mouth of the River de la Plata	53	0	39	30	1670	20	30
At the eastern entrance to Magellan's Straits	68	0	52	30	1670	17	0
At the western entrance to those Straits	75	0	53	0	1670	14	10
Baldivia	73	0	40	0	1670	8	10
Cape Aguillas	16	30 East	34	50	1672	2	0 West
	—	—	—	—	1675	8	0
At Sea	1	0	34	30	1675	0	0
	20	0 West	34	0	1675	10	30 East
	32	0	24	0	1675	10	30
The Island of St. Helena	6	30	16	0	1677	0	40
——— Ascension	14	30	7	50	1678	1	0
——— St. John	44	0 East	12	15	1675	19	30 West
——— Mombaza.	40	0	4	0	1675	16	0
——— Socotora	56	0	12	30 N.	1674	17	0
Aden, at the entrance to the Red Sea	47	30	13	0	1674	15	0
Terra Diego Roiz	61	0	20	0 S.	1676	20	30
At Sea	64	30	0	0	1676	15	30
	55	0	27	0	1676	24	0
Bombay	72	30	19	0 N.	1676	12	0
Cape Comorin	76	0	8	15	1680	8	48
Ballasora	87	0	21	30	1680	8	20
Fort St. George	80	0	13	15	1680	8	10
In the west of Java	104	0	6	40 S.	1676	3	10
At Sea	58	0	39	0	1677	27	30
The Island of St. Paul	72	0	38	0	1677	23	30
Van Dieman's Land	142	0	42	25	1642	0	0
New Zealand	170	0	40	50	1642	9	0 East
The Island of the Three Kings, in New Zealand	169	30	34	35	1642	8	40
The Island of Rotterdam	184	0	20	15	1642	6	20
The Shore of New Guinea	149	0	4	30	1643	8	45
The western point of New Guinea	126	0	0	26	1643	5	30

VII.

The following Table occurs among Christian Wolff's "Experimenta," vol. iii., p. 197.

Longitude from London.		Latitude.			Declination.	
Deg.	Min.	Deg.	Min.	Year.	Deg.	Min.
0	0	34	30 S.	1675	0	0
16	30 East	34	50	1675	8	0 West
40	0	4	0	1675	16	0
44	0	12	15	1675	19	30
47	30	13	0 N.	1674	15	0
55	0	17	0 S.	1676	24	0
56	0	12	30	1674	17	0
58	0	39	0	1677	23	30
61	0	20	0	1676	20	30
64	30	0	0	1676	15	30
72	0	39	0	1677	27	30
72	30	19	0 N.	1676	12	0
76	0	8	15	1680	8	48
80	0	13	15	1680	8	10
87	0	21	30	1680	8	20
126	0	0	26 S.	1643	5	30 East
142	0	42	25	1642	0	0
149	0	4	30	1643	8	45
169	30	34	35	1642	8	40
170	0	40	50	1642	9	0
184	0	20	15	1642	6	20
6	30 West	16	0	1677	0	40
14	30	7	50	1678	1	0
20	0	34	0	1675	0	0
31	30	43	50 N.	1682	5	30 West
32	0	24	0 S.	1685	10	30 East
32	30	8	0	1670	5	30
41	10	22	40	1670	12	10
42	0	21	0 N.	1678	0	40
50	0	38	40	1682	7	30 West
53	0	38	30 S.	1670	20	30 East
57	0	53	0	1670	14	10
57	0	61	0 N.	1668	29	30 West
68	0	52	20 S.	1670	17	0 East
73	0	40	0	1670	8	10
79	40	51	0 N.	1668	19	15 West
80	0	78	0	1661	57	0

VIII.

*A Table of Magnetic Declinations observed at Paris.**

Year.	Declination towards the East.		Year.	Declination towards the West.	
	Deg.	Min.		Deg.	Min.
1550	8	0	1706	9	48
1580	11	30	1707	10	10
1610	8	0	1708	10	15
1640	3	0	1709	10	15
1664	0	40	1710	10	50
	Towards the West.		1711	10	50
1666	0	0	1712	11	15
1670	1	30	1713	11	12
1680	2	40	1714	11	30
1681	2	30	1715	11	10
1683	3	50	1716	12	20
1684	4	10	1717	12	20
1685	4	10	Another month	12	45
1686	4	30	1718	12	30
1692	5	50	1719	12	30
1693	6	20	1720	13	0
1695	6	48	1721	13	0
1696	7	8	1722	13	0
1698	7	40	1723	13	0
1699	8	10	1724	13	0
1700	8	12	1725		
1701	8	25	November 6	13	15
1702	8	48	December 30	13	15
1703	9	6	1726, Dec. 6	13	45
1704	9	20	1727, Dec. 1	14	0
1705	9	35	1728, Jan. 3	14	0

IX.

A Table of Magnetic Declinations observed at London.

	Year.	Declination.	
		Deg.	Min.
By Burroughs	1576	11	15 East.
	1612	6	0
By Gunter	1622	6	10
By Gellibrand	1634	4	5
By Bond	1657	0	0

* The *original* tables 8, 9, 10, the Translator has not succeeded in finding.—*(Tr.)*

	Year.	Declination. Deg.	Min.
	1665	1	22½ West
	1666	1	35 : 36
By Halley........	1672	2	30
	1683	4	30
	1692	6	0
	1700	8	0
By Graham	1722, March 8	14	22

X.

Observations of Magnetic Declination made at Berlin, by Kirchius.

Year.		Month.	Declination.
1717	:	June	10° 42′
	:	26 Nov.	10° 55′
1724	:	13 Aug.	11° 45′
1725	:	14 June	10° 56′

XI.

Declinations taken in the Baltic.—(Phil. Trans., No. 364.*)*

	Latitude North.	Declination West.
At Revell, in 1720	58° 58′	14° 53′
At Gothland, 1720	58° 21′	14° 50′
At Bornholm, 1720	56° 0′	14° 44′
(In the year 1730, during the month of October, I took the declination at Salberg, or at the Silver Mine of Sahla, where the latitude is 60°, and the longitude 16° 17′ east from London: the declination was)		(9° 30′)

XII.

A Table, containing the Magnetic Declination as observed in four voyages to Hudson's Bay, from 1721 *to* 1725 ; *extracted from the Philosophical Transactions, No.* 393.

Latitude. Deg.	Min.	Longitude from London. Deg.	Min.	Variation. Deg.	Min.
50	0	12	0	14	0
51	0	12	0	14	15
52	0	12	0	14	30
53	0	12	0	14	45

Latitude.		Longitude from London.		Variation.	
Deg.	Min.	Deg.	Min.	Deg.	Min.
54	0	12	0	15	0
55	0	12	0	15	15
56	0	12	0	15	30
57	0	12	0	15	45
58	0	12	0	16	0
59	0	12	0	16	15
50	0	14	15	15	0
51	0	14	15	15	15
52	0	14	15	15	30
53	0	14	15	15	45
54	0	14	15	16	0
55	0	14	15	16	15
56	0	14	15	16	30
57	0	14	15	16	45
58	0	14	15	17	0
59	0	14	15	17	15
50	0	16	30	16	0
51	0	16	30	16	15
52	0	16	30	16	30
53	0	16	30	16	45
54	0	16	30	17	0
55	0	16	30	17	15
56	0	16	30	17	30
57	0	16	30	17	45
58	0	16	30	18	0
59	0	16	30	18	15
50	0	18	45	17	0
51	0	18	45	17	15
52	0	The same		17	30
53	0	throughout		17	45
54	0			18	0
55	0			18	15
56	0			18	30
57	0			18	45
58	0			19	0
59	0			19	15
50	0	21	0	18	0
51	0	21	0	18	15

Latitude.		Longitude from London.		Variation.	
Deg.	Min.	Deg.	Min.	Deg.	Min.
52	0	21	0	18	30
53	0	The same		18	45
54	0	throughout		19	0
55	0			19	15
56	0			19	30
57	0			19	45
58	0			20	0
59	0			20	15
50	0	23	15	19	0
51	0	The same		19	15
52	0	throughout		19	30
53	0			19	45
54	0			20	0
55	0			20	15
56	0			20	30
57	0			20	45
58	0			21	0
59	0			21	15
50	0	25	30	20	0
51	0	The same		20	15
52	0	throughout		20	30
53	0			20	45
54	0			21	0
55	0			21	15
56	0			21	30
57	0			21	45
58	0			22	0
59	0			22	15
50	0	27	45	21	0
51	0	The same		21	15
52	0	throughout		21	30
53	0			21	45
54	0			22	0
55	0			22	15
56	0			22	30
57	0			22	45
58	0			23	0
59	0			23	50

Latitude.		Longitude from London.		Variation.	
Deg.	Min.	Deg.	Min.	Deg.	Min.
50	0	30	0	22	0
51	0	The same		22	15
52	0	throughout		22	30
53	0			22	45
54	0			23	0
55	0			23	15
56	0			23	30
57	0			23	45
58	0			24	0
59	0			24	15
50	0	32	15	23	0
51	0	The same		23	15
52	0	throughout		23	30
53	0			23	45
54	0			24	0
55	0			24	15
56	0			24	30
57	0			24	45
58	0			25	0
59	0			25	15
50	0	34	30	24	0
51	0	The same		24	15
52	0	throughout		24	30
53	0			24	45
54	0			25	0
55	0			25	15
56	0			25	30
57	0			25	45
58	0			26	0
59	0			26	15
50	0	36	45	25	0
51	0	The same		25	15
52	0	throughout		25	30
53	0			25	45
54	0			26	0
55	0			26	15
56	0			26	30
57	0			26	45
58	0			27	0
59	0			27	15

Latitude.		Longitude from London.		Variation.	
Deg.	Min.	Deg.	Min.	Deg.	Min.
50	0	39	0	26	0
51	0	The same		26	15
52	0	throughout		26	30
53	0			26	45
54	0			27	0
55	0			27	15
56	0			27	30
57	0			27	45
58	0			28	0
59	0			28	15
50	0	41	15	27	0
51	0	The same		27	15
52	0	throughout		27	30
53	0			27	45
54	0			28	0
55	0			28	15
56	0			28	30
57	0			28	45
58	0			29	0
59	0			29	15
50	0	43	30	28	0
51	0	The same		28	15
52	0	throughout		28	30
53	0			28	45
54	0			29	0
55	0			29	15
56	0			29	30
57	0			29	45
58	0			30	0
59	0			30	15
51	0	46	0	29	0
52	0	The same		29	15
53	0	throughout		29	30
54	0			29	45
55	0			30	0
56	0			30	15
57	0			30	30
58	0			30	45
59	0			31	0

Latitude.		Longitude from London.		Variation.	
Deg.	Min.	Deg.	Min.	Deg.	Min.
52	0	48	30	30	0
53	0	The same throughout		30	15
54	0			30	30
55	0			30	45
56	0			31	0
57	0			31	15
58	0			31	30
59	0			31	45
53	0	51	0	31	0
54	0	The same throughout		31	15
55	0			31	30
56	0			31	45
57	0			32	0
58	0			32	15
59	0			32	30
60	0			32	45
54	0	54	0	32	0
55	0	The same throughout		32	15
56	0			32	30
57	0			32	45
58	0			33	0
59	0			33	15
60	0			33	30
61	0			33	45
54	0	57	0	33	0
55	0	The same throughout		33	15
56	0			33	30
57	0			33	45
58	0			34	0
59	0			34	30
60	0			35	0
61	0			35	30
55	0	60	0	34	0
56	0	The same throughout		34	30
57	0			35	0
58	0			35	30
59	0			36	0
60	0			36	30
61	0			37	0
57	0	63	0	35	0
58	0	The same throughout		35	30
59	0			36	0
60	0			36	30
61	0			37	0
62	0			37	30
59	0	66	0	37	0
60	0	The same throughout		37	40
61	0			38	20
62	0			39	0
63	0			39	40
60	0	69	0	41	0
61	0	69	0	41	40
62	0	69	0	42	20
60	0	72	0	40	0
61	0	72	0	42	0
61	40	72	0	42	40
62	0	78	0	43	0
63	0	78	0	44	0
63	50	78	0	46	0
61	0	75	0	38	0
62	0	75	0	43	0
62	50	75	0	45	0
63	0	81	0	43	0
64	0	81	0	46	0
62	0	82	0	39	0
63	0	82	0	44	0
61	0	84	0	33	45
62	0	84	0	40	0
63	0	84	0	42	0
60	0	86	0	30	0
61	0	86	0	33	0
62	0	86	0	35	0

Latitude.		Longitude from London.		Variation.	
Deg.	Min.	Deg.	Min.	Deg.	Min.
59	0	88	0	28	0
60	0	88	0	28	40
61	0	88	0	29	20
57	0	90	0	24	0

Latitude.		Longitude from London.		Variation.	
Deg.	Min.	Deg.	Min.	Deg.	Min.
58	0	90	0	24	30
59	0	90	0	25	0
57	0	94	0	23	0
58	0	95	0	22	30
59	0	95	0	21	0

XIII.

Observations on the Declination of the Magnet, given in the German "Ephemerides Natur. Curios.," decur. 2, an. 2, p. 446; *the first meridian drawn through Teneriffe: for the year* 1675; *taken by Leydekker.*

The Day of the Year.		Latitude.			Longitude.			Declination East.	
	April.	Deg.	Min.		Deg.	Min.	Sec.	Deg.	Min.
1675,	12	0	20	North	358	0	0	1	36
	22	4	25	South				2	3
	23	5	55		357	31	15	3	48
	24	7	23					4	0
	25	8	40					4	15
	26	9	52		356	51	30	4	30
	27	11	26					4	48
	28	13			356	33	45	4	15
	29	14	13		356	20	30	5	52
	30	15	14					6	30
May	2	17	8		356	1	45	6	37
	8	25	36		352	5	55	11	55
	15	34	26		2	50	0	11	15
	17	34	14		7	23	15	7	30
	21	35	30		15	2	0	4	2
	23	36	8		18	47	15	3	28
								West.	
	26	35	15		25	58	15	0	48
	27	34	42		27	33	0	2	8
	29	34	9		32	52	45	5	28
	30	33	46		36	40	0	7	30
June	20	36	35		39	20	0	—	—
	22	38	25		41	14	0	11	30
	25	—	—		50	20	0	16	0
	28	37	28		57	50	0	20	40
	29	37	49		60	0	0	21	45

The Day of the Year.	Latitude.		Longitude.			Declination West.	
June.	Deg.	Min.	Deg.	Min.	Sec.	Deg.	Min.
30	38	3 South	62	4	15	23	0
July 5	37	33	77	25	30	26	30
6	37	45	80	18	0	26	45
7	—	—	82	0	0	25	44
9	38	14	87	25	45	25	30
10	—	—	—	—	—	22	22
12	38	3	96	20	0	22	44
13	37	1	98	0	0	21	30
15	35	54	103	0	0	18	40
19	28	46	111	36	30	10	3
21	26	50	—	—	—	7	54
22	25	22	116	17	45	7	30
23	23	30	—	—	—	7	0
25	20	26	118	43	0	6	40
29	14	10	122	6	0	4	15
30	12	0	122	12	15	3	45
31	11	28	122	30	0	2	0
August 1	9	0	123	1	45	2	10

XIV.

Magnetic Declinations observed in the year 1708, *by Fueilleè, on a voyage to America.*

Latitude.		Longitude.		Declination.	
Deg.	Min.	Deg.	Min.	Deg.	Min.
		Cagliari in Sardinia		10	19 West
35	35 North	Malta		10	25
39	54	Port Mahon		10	26
5	49	354	52	0	7
5	24	357	3	0	0
Under the equator		354	0	0	37 East
2	26 South	353	3	1	5
8	4	352	39	1	17
13	3	351	46	3	32
20	21	350	27	8	11
21	10	349	21	8	4
21	53	348	8	7	46
22	8	347	25	9	8
22	20½	346	58½	9	28
22	44½	346	6½	9	0

Latitude.		Longitude.		Declination.	
Deg.	Min.	Deg.	Min.	Deg.	Min.
27	5 South	355	52	12	17 East
28	55	331	21	12	0
31	0	329	7	16	24
34	18	327	49	18	17
41	11	322	46	19	19
42	16	322	15	17	57
43	24	321	49	19	57
46	24	319	44	19	16
53	0	315	29	23	5
55	45½	318	9	23	3½
51	26	299	29	15	0
49	51½	299	54	13	30
41	4	303	20	11	33
33	1	Valparaiso		9	30
13	9½	Lima		6	15

XV.

Variations observed in the Great South Sea, from the South Cape of California to the Island of Guana or Guam, one of the Ladrones; from the Philosophical Transactions, No. 368: *the meridian passing through London; for the years* 1709 *and* 1710.

Latitude.		Longitude West.		Declin. East.	
Deg.	Min.	Deg.	Min.	Deg.	Min.
22	16	114	9	3	0
21	18	114	42	2	50
20	24	115	15	2	50
19	25	115	45	2	50
18	56	116	24	2	45
18	0	117	6	2	45
17	11	117	30	2	15
16	32	118	5	2	0
15	44	118	54	1	50
15	0	120	15	1	30
14	49	122	5	1	10
14	36	124	25	0	50
14	24	126	45	0	40
14	14	129	5	0	45
13	50	131	23	0	50
13	29	132	58	1	0
13	29	134	41	1	10
13	22	136	48	1	15
13	27	139	21	1	25
13	32	142	7	1	30
13	32	144	37	1	40
13	36	147	32	1	50
13	26	150	18	2	0
13	26	153	2	2	10
13	26	155	19	2	25
13	26	157	43	2	30
13	25	160	31	2	50
13	41	163	0	3	0

Latitude.		Longitude West.		Declin. East.	
Deg.	Min.	Deg.	Min.	Deg.	Min.
13	41	165	18	3	20
13	44	167	26	3	30
13	36	169	56	3	45
13	33	172	27	4	0
13	36	175	0	4	30
13	32	177	21	5	20
13	40	179	28	6	30
13	47	181	24	7	0
13	54	183	22	7	30
13	52	185	37	9	0
13	40	187	42	10	15
13	28	189	49	11	0
13	21	191	30	11	30
13	12	193	25	12	0
13	7	194	37	11	50
13	10	195	51	11	0
13	3	197	51	10	0
13	0	199	3	9	50
12	57	200	16	9	30
12	54	202	20	9	0
12	58	204	12	8	40
13	4	206	6	8	20
13	5	207	33	8	0
13	5	209	4	7	50
13	2	211	54	7	30
13	7	212	42	7	10
13	7	214	7	7	0
13	3	215	28	6	50
13	8	217	11	6	30
13	16	218	27	5	40

Island of Guana in sight.

XVI.

Declinations of the Magnet observed by Noel, on a voyage to the East Indies, in the year 1706.

Latitude.			Declination.	
Deg.	Min.	Longitude.	Deg.	Min.
—	—	At Lisbon	6	30 West
18	20 North	50 miles from Cape Verd	1	15
14	0	A little nearer Cape Verd	0	0
4	—	2 deg. from the Ferro Islands, west ..	0	0
0	0	3 deg. from the Ferro Islands, west ..	1	30 East
7	28 South	150 miles from Brazil	3	0
11	20	In the same longitude	4	0
15	15	In the same longitude	4	45
25	40	700 miles from the Cape of Good Hope	3	20
27	10	600 miles from the Cape of Good Hope	2	30
31	45	360 miles from the same	0	0
33	48	250 miles from the same	4	0 West
35	10	In sight of the Cape of Good Hope ..	13	40
36	40	200 miles from the same Cape towards the east	18	30
35	40	250 miles from the same Cape towards the east	22	0

Latitude. Deg.	Min.	Longitude.	Declination. Deg.	Min.
36	0 South	Under the meridian of the Island of Madagascar	36	0 West
34	44	600 miles from the Cape of Good Hope	22	0
30	40	800 miles from the same Cape	20	0
28	15	On the same voyage towards the east	16	0
27	44	950 miles from the same Cape	15	0
24	54	1200 miles from the same Cape	10	0
23	8	1300 miles from the same	8	40
19	39	1450 miles from the same	6	0
14	37	In the vicinity of Borrapheliote	2	40
4	20	30 miles from Sumatra	0	0
2	40	Under the meridian of the City of Acheen in that Island	1	30
0	0	Under the meridian of Bengal	3	0
4	50	Between the meridian of the preceding and Ceylon	4	0
7	50	Near Batcola in Ceylon	4	0
9	0	On the shore of the City of Cochin	6	20
13	30	Near the City of Goa	6	40

XVII.

In the year 1718, *on a voyage in the Sea of Sunda, towards Brazil.*

Latitude. Deg.	Min.	Longitude.	Declination. Deg.	Min.
10	15 South	100 miles from the Sea of Sunda	3	0 West
13	50	180 miles from the former place	4	20
16	0	80 miles from the last place	7	0
18	48	144 miles from the last place	9	0
21	4	120 miles from the last place	11	20
22	8	40 miles from the last place	11	20
24	8	100 miles from the last place	16	50
26	27	80 miles from the last place	19	20
28	47	124 miles from the last place	24	0
30	12	86 miles from the last place	26	16
30	30	70 miles from the last place	24	30
31	0	23 miles from the last place	23	0
33	21	100 miles from the last place	20	0
35	30	180 miles from the last place	15	40

Latitude. Deg.	Latitude. Min.		Longitude.	Declination. Deg.	Declination. Min.	
34	50	South	70 miles from the last place, that is, towards the Cape of Good Hope ..	14	0	West
34	45		70 miles from the Cape towards Brazil	11	0	
30	4		139 miles from the last place	4	30	
18	57		250 miles from the last place	2	0	East
13	30		320 miles from the last place	6	0	
13	10		Near the port of Boha in Brazil......	11	30	

XVIII.

The Variation of the Compass, or Magnetic Needle, in the Atlantic and Ethiopic Oceans, A.D. 1706*; from the Philosophical Transactions, No.* 310, p. 2433. *The first meridian passes through London.*

Latitude. Deg.	Latitude. Min.		Longitude. Deg.	Longitude. Min.		Declination. Deg.	Declination. Min.	
49	18	North	7	29	West	8	32	West
44	31		13	45		6	42	
41	6		15	8		5	30	
40	22		14	54		5	4	
39	11		15	35		4	22	
32	21		15	39		3	30	
32	42		15	38		3	35	
18	50		20	52		1	20	
9	26		17	59		1	14	
0	49		18	42		1	10	
1	9	South	18	58		1	0	
2	32		19	48		0	16	
3	17		20	5		0	0	
3	58		20	27		0	40	East
5	9		21	39		1	2	
6	21		22	8		1	30	
8	3		23	15		1	50	
9	7		23	35		2	10	
12	3		25	3		3	32	
18	53		26	30		6	4	
19	51		27	2		6	19	
21	26		28	14		6	20	

Latitude.			Longitude.			Declination.		
Deg.	Min.		Deg.	Min.		Deg.	Min.	
21	48	South	28	10	West	6	30	East
21	58		28	23		7	0	
24	45		27	56		6	45	
27	11		27	17		6	36	
33	53		16	58		5	4	
34	21		1	29	30″	0	0	
34	15		1	33	East	1	0	West
33	41		6	23		4	16	
34	39		13	2		8	46	
34	30		16	15	At the Cape of Good Hope.	11	56	
32	51		13	41		11	30	
30	21		11	46		10	0	
29	51		11	44		9	44	
29	28		11	31		9	34	
28	56		11	5		9	22	
27	38		10	1		9	4	
26	55		8	45		8	30	
25	41		7	22		8	2	
24	32		5	43		7	32	
16	0		6	30	West; at the Isle of St. Helena.	1	52	

XIX.

Magnetic Declinations observed in the year 1703, *given in the Histoire de l'Acad. Roy.*, 1705, *Mem. p.* 10*: the first meridian passes through the Ferro Islands.*

Latitude.			Longitude.		Declination.		
Deg.	Min.		Deg.	Min.	Deg.	Min.	
5	40	North	358	0	1	30	West
5	20	South	356	—	1	0	East
11	15		352	40	1	30	
21	0		350	0	6	30	
34	40		7	45	3	15	
36	0		24	10	3	0	West
36	20		41	0	13	0	
35	35		53	30	19	0	
32	50		69	0	25	30	
28	0		98	30	19	0	
22	40		96	35	15	0	
1	20		106	40	4	0	
14	40		105	20	4	45	

XX.

A Table of Magnetic Declination, made by Houssaye, in the years 1704 *and* 1705 *: the first meridian passing through the Peak of Teneriffe: given in the Histoire de l'Acad. Roy,* 1708, *Mem. p.* 174.

Latitude.		Longitude.	Declination.	
Deg.	Min.		Deg.	Min.
—	—	The place, Port Louis, France.	5	0 West
22	0 North	357° 0′	0	0
16	30 South	353° 45′	2	30 East
18	0	354° 0′	3	30
23	0	354° 0′	3	30
—	—	The same	11	0 A.D. 1682
28	0	357° 0′	6	0
—	—	In sight of the Cape of Good Hope. .	9 to	10 West
—	—	The western part of the Needle's Bank	12	0
—	—	The eastern part	13	30 to 14
—	—	The Cape of Good Hope	7 to 7	30 A.D. 1680
—	—	The Mozambique Channel	22 to	23
—	—	In 1711, Kolbe observed the declination here to be	11	55
—	—	To the Bay of St. Augustin	less than	21¾ A.D. 1704
—	—	In sight of the Island of Jean de Nova	22	0
—	—	In sight of the Mayotte Islands, Amzuam and Moëly	20	30
0	0	70° 0′	16	0
15	0 North	87° 0′	10	30
16	30	In sight of Canara, and along Malabar	6	30
—	—	At Cape Comorin	7	30
—	—	In Ceylon, at point de Galle	5	30
—	—	Near Coromandel	5	0
—	—	Near the Andaman and Nicobar Islands	3	0
—	—	In sight of the Island of Diego Roiz . .	16	30
—	—	In sight of the Mauritius	21	0
—	—	In sight of the Island of Bourbon . .	21	30 to 2 22
25	0 South	74° 0′	23	30
27	15	72° 45′	24	30
33	10	65° 45′	24	30

Latitude. Deg.	Min.		Longitude.	Declination. Deg.	Min.	
—	—	South	The Island of St. Helena	1 to 1	20	West
—	—		The Island of Ascension	0 or 1		East
0	0		357° to 358°	0	0	
—	—		In sight of the Island of Corvo Flores	4 to 4	30	West
—	—		At Newfoundland	7 to 8		
—	—		Coast of Britain	5	0	

XXI.

A Table of Magnetic Declination, given in the Histoire de l'Acad. Roy., 1710, *Mem. p.* 358; *the meridian passing through the Peak of Teneriffe.*

Latitude. Deg.	Min.		Longitude.	Declination. Deg.	Min.	
44	45	North	120 leagues from the French coast, A.D. 1708 and 1709	8	0	West
45	7		11° 31′	6	40	
45	20		358° 15′	11	0	
35	35		0° 0′, A.D. 1708	4	35	
27	58		353° 40′	4	32	
36	0		325° 46′	5	8	
46	50		From Rochelle 230 leagues, 1709	7	50	
33	45		5° 0′	6	0	
43	45		340° 46′	13	0	
44	45		52 leagues from Cape Finisterre, 1707	7	20	
—	—		In sailing 60 leagues to the west	7	20	
7	15	South	1° 50′	2	30	
—	—		Roads of Juda, coast of Guinea, 1708	8	20	
—	—		——————— 1705	8	0	
—	—		St. Thomas	11	30	
28	30	North	316° 30′, 1709	1	30	
32	15		321° 45′	4	10	
36	50		329° 0′	7	10	
45	8		305° 30′	10	10	

If these observations are well taken, then, at the parallel of 22 degrees south latitude, the line void of magnetic declination would have approached to the west 120 miles from the year 1700 to 1708; according to Muschenbroek.

XXII.

A Table of Observations on the Variation of the Compass, in the Ethiopic Ocean in the year 1721, *and the beginning of* 1722, *by Captain Cornwall; from the Philosophical Transactions, No.* 371; *the meridian distance being reckoned from St. Jago.*

Latitude.		Meridian Distance.		Longitude.		Declination.	
Deg.	Min.	Deg.	Min.	Deg.	Min.	Deg.	Min.
9	8 South	9	23 West	9	25 West	2	13 East
11	12	10	46	10	50	4	30
11	34	11	28	11	41	4	29
12	32	11	31	11	43	4	27
15	46	10	53	11	6	6	10
16	26	8	25	8	30	7	16
18	45	9	31	9	39	6	17
19	47	9	10	10	0	8	6
28	43	1	7	1	9 East	5	53
31	33	3	41 East	3	56	4	10
33	30	11	29	12	57	0	11 West
32	40	19	6	12	1	3	0
32	53	21	18	24	59	5	41
32	30	25	33	30	0	7	47
32	28	30	37	35	52	8	44
31	22	31	40	37	7	10	57
31	11	32	4	37	47	11	20

XXIII.

Observations on the coast of Africa, in the years 1721 *and* 1722, *extracted from the same Transactions as the last.*

Latitude.		Meridian Distance.		Longitude.		Declination.	
Deg.	Min.					Deg.	Min.
26	17 South	35	35 East	41°	41′ East	14	30 West
19	41					12	22
17	4					14	29
13	56					14	48
10	57					13	11
8	19					15	14
5	0	In Cabenda Bay				14	33
		From Cabenda to London.					
3	25	11	38 West	11	43 West	11	32
3	30	21	18	21	24	—	—
0	30	30	41	30	46	1	5
10	50 North	39	8	39	16	1	1 East
17	15	43	21	43	29	1	41

XXIV.

Observations of Declinations taken in the year 1706, *by Verune, described in the Histoire de l'Acad. Roy., anno* 1708, *Mem., p.* 295 : *in which the first meridian is reckoned through the Peak of Teneriffe.*

Latitude.			Longitude.	Declination.		
Deg.	Min.			Deg.	Min.	
20	44	South	345° 44′ Near the Island of Ascension, 1706	7	30	East
56	6		297° 12′ Near the Island of Hermite, 1707	20	0	
52	19		310° 30′ Sebald's Island	23	0	
13	6		300° 10′ Near Point Canette............	7	0	
14	1		296° 27′ Near Pisco	7	0	
31	49		297° 30′ Valparaiso	8	0	
36	30		299° 25′ Near Conception..............	10	0	
44	49		In these instances, a short distance from the western coast of America	12	0	
48	58			13	0	
53	37			15	0	
56	42			17	0	

XXV.

Observations of Declinations collected in Dampier's voyage.

Latitude.		Longitude.	Declination.	
51° 25′	South	In the year 1683, in the Islands of Sibbel de Wards..........................	23° 10′	East
— —		In 1707	23° 0′	
47° 10′		In the Pacific Ocean, in 1683............	15° 30′	
36° 0′		In the same.........................	8° 00′	

XXVI.

Observations of Declinations in the year 1706, *described in the Histoire de l'Acad. Roy.,* 1710, *Mem., p.* 358.

Latitude.		Longitude.	Declination.		
Deg.	Min.		Deg.	Min.	
—	—	25 leagues from Porto Santo near Madeira	5	0	West
—	—	Near Madeira	4	30	
—	—	But at the S.W. between Madeira and the Island of Ferro	4	0	

Latitude.			Longitude.	Declination.		
Deg.	Min.			Deg.	Min.	
—	—		50 leagues towards S. S.W. from the Island of Ferro	3	0	West
18	15	North	357° 0′	2	30	
—	—		Between the former place and the Bank of Bisagos on the coast of Guinea, the declination is constantly observed to be	2	30	
6	0		358° 0′	2	0	
3	15		0° 10′	2	0	
0	0		7° 0′	2	0	
—	—		But 50 leagues further on, S.E.	3	0	
—	—		And 50 leagues further on	4 to	5	
9	0		356° 15′	5	0	
—	—		And 50 leagues further towards the S.W.	5 to	4	
—	—		50 leagues further in the same direction	4 to	3	
—	—		50 leagues further in the same direction	2 to	1	
—	—		Whence after sailing 250 leagues	0	0	
—	—		50 leagues further	1	0	East
—	—		20 leagues N.E. from the Island of Ascension	6	0	
—	—		The Island of Grande, off Brazil	11	40	
—	—		The Straits of Magellan	12	0	
—	—			13	0	
—	—			16	0	
—	—			17	0	
—	—			18	0	
—	—			19	0	
40	30	South		19	30	
—	—		The same declination remains under the same latitude for 60 leagues	19	0	
57	10		60 leagues S.W. from the Straits of Maire	26	0	
57	40		For 40 leagues	26	0	
—	—		Conception	9	30	
—	—		Pisco	8	0	
—	—		Canette	6	30	
—	—		Callao	6	0	
44	45		30 leagues from Chili	12	0	
44	45		120 leagues from Chili	7	0	
40 &	41		10 leagues from the coast	9	0	
40	41		130 leagues from the coast	6	0	
30 &	31		60 leagues from the coast	7	0	

Latitude. Deg.	Latitude. Min.	Longitude.	Declination. Deg.	Declination. Min.
30 &31 South		220 leagues from the Coast	5	0 East
—	—	In the year 1707, at the River Gallegue . .	23	0
—	—	60 leagues from Gallegue towards the Cape of Good Hope	22	0
—	—	30 leagues further	20	0
—	—	150 leagues further	18	0
—	—	110 leagues further	16	0
—	—	150 leagues further	14	0
—	—	60 leagues further	13	0
—	—	50 leagues further	12	0
—	—	20 leagues further	11	0
—	—	30 leagues further	10	0
—	—	20 leagues further	8	0
—	—	100 leagues further	4	0
—	—	120 leagues further	0	0
—	—	60 leagues further	2	0 West
—	—	80 leagues further	4	0
—	—	60 leagues further	7	0
—	—	140 leagues further	9	30
—	—	60 leagues further towards the Cape of Good Hope	8	0
33	30	530 leagues from the Cape of Good Hope towards the east	24	30

XXVI.

In the last place we have Halley's Map, made up to the year 1700 (plate xix.), and in which the declinations observed throughout the world, are denoted by lines. Respecting this map, Muschenbroek remarks as follows :—

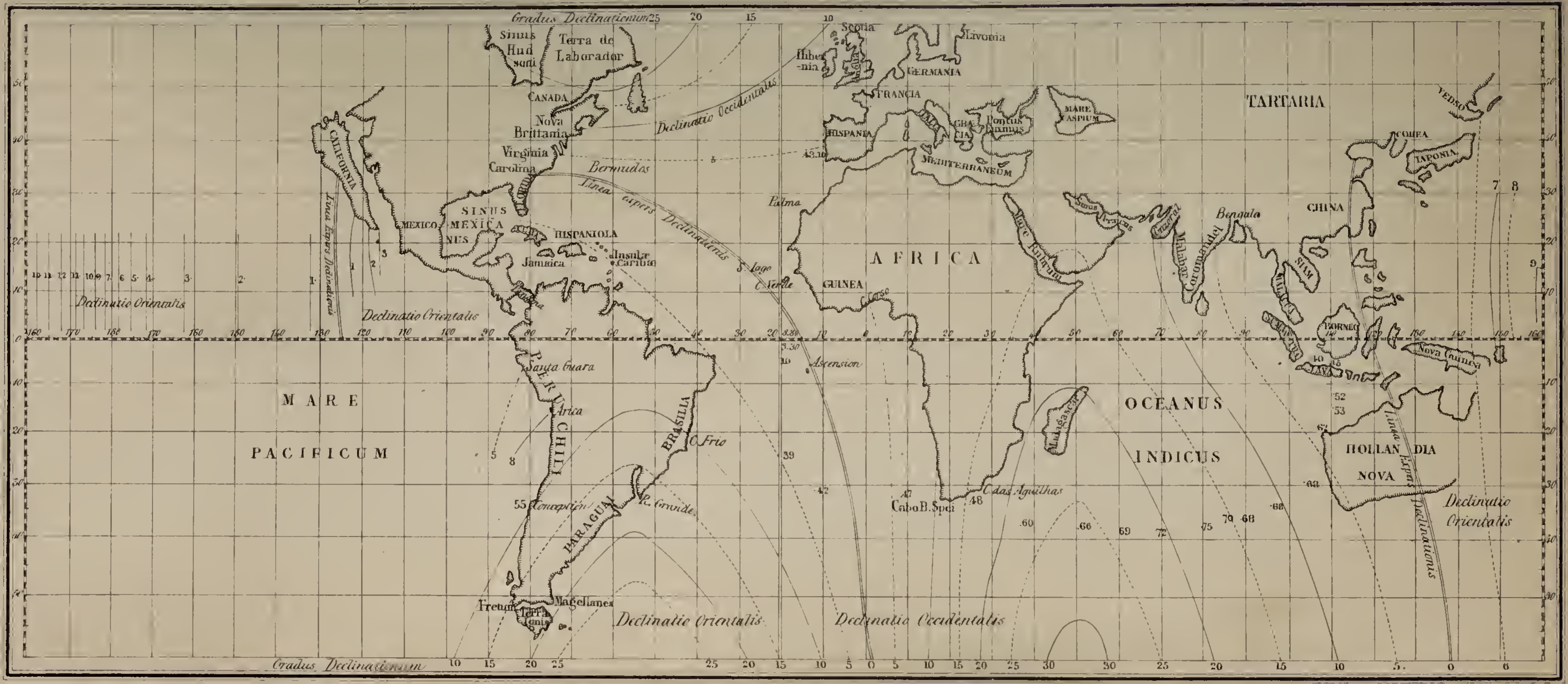
"From the rude chaos of observations, the sagacious and ingenious Halley has formed a kind of system, which although, as its philosophic author himself confesses, still imperfect, and subject to correction, is nevertheless confirmed more and more by the observations of every day. Hence we are bound to assume this system as a basis ; following the example of the savans of the Royal Academy of Paris, who use it, compare it with fresh observations made in different voyages, and rejecting all other hypotheses, correct, study, enlarge, and illustrate this alone. See the *Histoire de l'Acad. Roy.*, an. 1712. In order, therefore, that this matter, intricate as it is, may be clearly comprehended, Halley's magnetic map must be laid open before us: and must be the basis of all [our calculations]. This map represents almost the whole world; it also contains straight lines, exhibiting the meridians, drawn from the south pole to the north: it has also lines of latitude like those observed in common maps: and besides these, curved lines, which are for the purpose of shewing the direction of the magnet. This map is prepared for the year 1700, when the declination of the magnet was such as is denoted in the places alluded to. 1. There is a curve which begins in America, at Carolina, and passing through the Island of Bermuda, and through the Atlantic Ocean towards the south, ceases at the 58th degree of latitude in the meridian of London: this curve in the year 1700 passed over all those parts of the land and sea, which were void of magnetic declination; whence it is called by Halley, the line void of declination. 2. Above this line, towards the north, we see other curves, over against which are placed the numbers, 5, 10, 15, 20, 25, and they pass over the Western Ocean: the numbers indicate that the needle declined so many degrees towards the west in the places which lie under these curves.

"If we take another view of Halley's map, we shall find other curves between the line void of declination and America; which curves are drawn over the places which have exhibited the quantity of declination designated by the numbers 5, 10, 15, 20, 25; but in all these western places the declination is towards the east. The line to which the number 5 belongs, agrees very well with the observations made in the year 1706, but at a south latitude, it seems to be a little more elevated towards the line void of declination. The curve passing over the places in which the magnet declines for 10 degrees in the Pacific Ocean, I have continued onwards, and carried through the City of Valparaiso; because Frezier in his Itinerarium has remarked the declination there to be correspondent with that of the line. Halley has no observations taken in that sea. Did we know all the declinations which occur on the Pacific coasts of America, we might then complete what Halley has begun. I can now add only five other places, from the observations of Frezier and Feuilleè, at California, Santa, Guam, and Arica.

"The curves drawn to the east are partly over the Atlantic Ocean, and partly over the Indian Ocean, in all which there is a western declination, which is greatest at a south latitude of 54 degrees, and east longitude of 50 degrees. If we consult the observations from the *Philosophical Transactions*, No. 231, made in the year 1721, it will be plain that these curves have receded towards the east: for under the

Tabula Totius Orbis Terrarum.

Exhibens Declinationes Magneticas ad annum 1700. composita ab Edmundo Halleyo. simul cum Inclinationibus a Pouncio observatis.



Newbery Litho.

latitude 32° 40′, and longitude 12° 1′, we observe a declination of 3 degrees only, where Halley makes it 7 or 8 degrees. In the same place under the south latitude 31° 32′, and longitude 37° 7′, is placed the declination 10° 57′, where Halley makes it nearly 20 degrees." For further particulars we refer the reader to Muschenbroek.

CHAPTER XV.

ON THE CAUSES OF THE MAGNETIC DECLINATION.

In our former remarks upon first principles, it has been abundantly shewn that there is a certain element, at whose will the magnet is governed, and the motion and situation of whose particles the magnet obeys. This element I have called the magnetic; because it presents to our view its phenomena and natural mechanism more especially in the case of magnets; although it acts likewise upon the particles of ether, air, and other elements, which without an orderly sequence and series of smaller and greater particles could not subsist; on which subject we have treated in another place. We have therefore a most subtile magnetic element rendered visible to us principally by magnetic experiments. The particles of this element are, according to our fore-mentioned principles, of two kinds; smaller and larger; the smaller subsist by a pure natural mechanism; the larger, which immediately constitute the magnetic spheres, are both of themselves, and likewise by means of the smaller ones, held and preserved continually in their polar situation. By no particles of any other element can they be disturbed; because these are crasser, and so cannot act upon the magnetic particles except in a much crasser manner, and except upon their volumes. Since therefore every particle of this element, according to our principles, turns itself polarwise, and conjointly with its proximates adheres to the poles; it follows, that all in one series occupy a polar situation; that they observe a parallelism one to the other; and consequently bring into the same situation with themselves and likewise there maintain the spheres of the magnets.

2. This magnetic element possesses principally the solar vortex, or that of our universe or mundane system. It likewise enters into the vortices of the planets and earth, within which move the satellites and moons. The surface of the earth however is occupied by air, and still more proximately by water; but together with these and all the other elements there subsists the magnetic element. The air, however, and water do not penetrate into the expanse of the vortex, but occupy the proximate circuit of the earth; because their more material and crasser particles are driven thither by the smaller, by means of a certain centripetal force, of which we shall speak more at large in our theory of the tellurian vortex. The vortex therefore of our earth, for a considerable part, consists of particles of the magnetic element; for it is known that there is a vortex which surrounds the earth, and within which like a nucleus the earth is revolved; or is enfolded as an infant in the arms of its nurse; and since the element of the tellurian vortex is carried round by a certain spiral motion, it follows from our first principles that this vortex must, by reason of its spiral motion, form an ecliptic; although not a similar one at every distance from the centre or from the earth; also that it must form poles; also that at the poles apertures will be formed into the resemblance of cones, by means of which the element can flow in and also flow out on the opposite side. These are only consequences of every spiral motion existing among mobile and elementary particles. For if we grant the existence of a vortical and spiral motion between particles continually mobile, we must grant the existence of a motion conformable to a greater circle; whether we call this circle an equator or an ecliptic; we must grant also, upon the geometrical principles of motion flowing into a helix or spire, the existence of poles; as likewise apertures at the poles, and influxes and effluxes of the particles: without which there could be no continuous spiral motion. Moreover, particles of this kind are created and adapted to the formation of such a motion, for they possess this motion within themselves; in a word, the whole of their motion is vortical, according to the mechanism of their figure.

3. Since therefore there is no doubt that there is a vortical and spiral motion of particles in the vortex of our earth, and that hence are formed ecliptics and poles; it follows that the element which tacitly flows in at one pole and flows out at the other, has two poles; one on the south side of the earth, the other on its north side; and that from the south it pursues its course to the north, and so tends back again into its vortex, and repeats the course it before pursued. Thus there are two poles; one in the southern, and the other in the northern region.

Since therefore there are two poles, we may next enquire what is the distance between the poles of the earth or world. Now they cannot be the same with the poles of the earth, but are the same with the poles of the vortex. For as the vortex by its spiral motion forms ecliptics, so these poles must be the same with the poles of the ecliptic; that is to say, they will be at the same distance from the poles of the earth as the poles of the ecliptic, or 22° 30′. For if a vortex in its spiral motion forms mere ecliptics from the outermost part to the innermost, there can be no other poles to the vortex than those which are of the ecliptic, nor can there be any other magnetic poles than those of the ecliptics of the vortex; that is to say, they must be poles at a distance of 22° 30′ on each side from the poles of the earth.

4. We are next to consider, that the influx of the particles of this element is at the south pole, and that hence it tends to the north; not like a stream and torrent, but like a tranquil and tacit current [*alvei*], which gradually and without any sensible motion, pursues its course from one haven to another. Nevertheless this force, small as it is, must be taken into consideration; for without it we shall by no means be enabled to arrive at the true knowlege of the declination.

5. Another thing we have to consider is, that this stream tends from the south pole to the north in a spiral manner; for it does not flow directly from one pole to the other, because it flows in spirally by polar cones, and embraces the surface of the earth by preserving the motion and pression of a spire, until it comes to the other pole, or cone of emergence. For the motion begun is spiral, which cannot terminate rectilineally; especially

when it is received or taken up by a spiral motion in the north cone. This spire also must be taken into consideration in our calculation of the declination of the magnet.

6. That the poles themselves are in motion and perform a certain gyration within a certain time around the poles of the earth, although always at the same distance from them, is sufficiently evident from experiments. But both from experiment and from our first principles, which remain to be more especially explained in our theory of the tellurian vortex, it is evident, that the north magnetic pole moves round the north tellurian pole, sooner than the south magnetic pole moves round the south tellurian; and this because the distance of the two from the centre of the vortex is not similar, and because also of the spiral contorsion of the vortex. In the same theory we shall have to demonstrate, that these magnetic poles move round the pole of the earth continually from west to east, and thus in a circuit; but with uneven progress. But inasmuch as both poles have not the same motion, they cannot return to their original situation till after several ages; nor can they till after several ages present the same series of declinations. The north magnetic pole, which is distant from the north tellurian pole 22° 30′, performs its entire circle round the north pole of the earth within about 386 years, and this from west to east; or what amounts to the same, it progresses in its circle every year 56′. But the south magnetic pole, which is distant from the south tellurian pole 22° 30′, does not complete its circuit till within 1080 years, or progresses every year 20′ or the third part of a degree; so that the difference of motion in the poles is as 386 to 1080; or as 20 to 56. From which it follows, that the poles cannot return to their original situation till after several circuits; that is to say, till after several ages; or until the north magnetic pole has completed 14 circuits, or the south pole 5; which it cannot do till the lapse of 5400 years.

7. But inasmuch as the poles move from west to east around the poles of the earth, and always at the same distance from them; and inasmuch as they cannot return to their original position till after several ages; we must ascertain the situation of the poles in some given year, from which we must then cal-

culate their progression. This situation cannot be ascertained from any mere theory; for it is always different, and is every year changing; hence it is necessary to call into aid experience, which, after much labour and calculation, has taught me that in the year 1720 the north magnetic pole was distant westward from the London meridian 112°; that is to say, that in the year 1720 there was between the meridian passing through the pole, and the London meridian, an angle of about 112°; and that in the same year 1720, the south magnetic pole was distant from the London meridian westward an angle of 145° 30′; that is to say, between the meridian passing from the pole of the earth through the magnetic pole and the London meridian there was an angle westward of 145° 30′. These angles cannot be known but from actual observation, which will confirm our foregoing remarks.

8. Such as is the situation of the particles of the magnetic element, such will be the situation of the magnet when left to itself, or of the mariner's needle. For this element directs the sphere and at the same time the body of the magnet into a parallelism and similarity of situation with its own: or more clearly thus; such as is the situation of the particles of the magnetic element, such also is the declination. As for example; at Paris in the year 1727, where the declination was observed to be 14° 0′ to the west, then in the same place the very particles of the element inflect themselves at an angle of 14° from the north pole of the earth toward the west, and consequently so also does the needle.

The magnetic element itself does not appear to be able to operate immediately upon the needle or magnet, and by any influx or efflux to direct it into that position; but it seems to operate only upon the sphere by which the magnet or needle is surrounded, and urges it into a position parallel to itself; whence the sphere also urges in like manner the magnet or the needle. This it is which appears to be the genuine cause of the declination, as will be still more manifest in the sequel.

The question is therefore, what is the situation of the particles of the magnetic element at any given place on the earth, and what is the cause of this situation being so different in one place from what it is in another; or what amounts to the same, what is the cause of the declination of the needle being so different all over the world. If this question receives a right solution, we shall then arrive at the true cause of the magnetic declination; for on the former question hinges the latter.

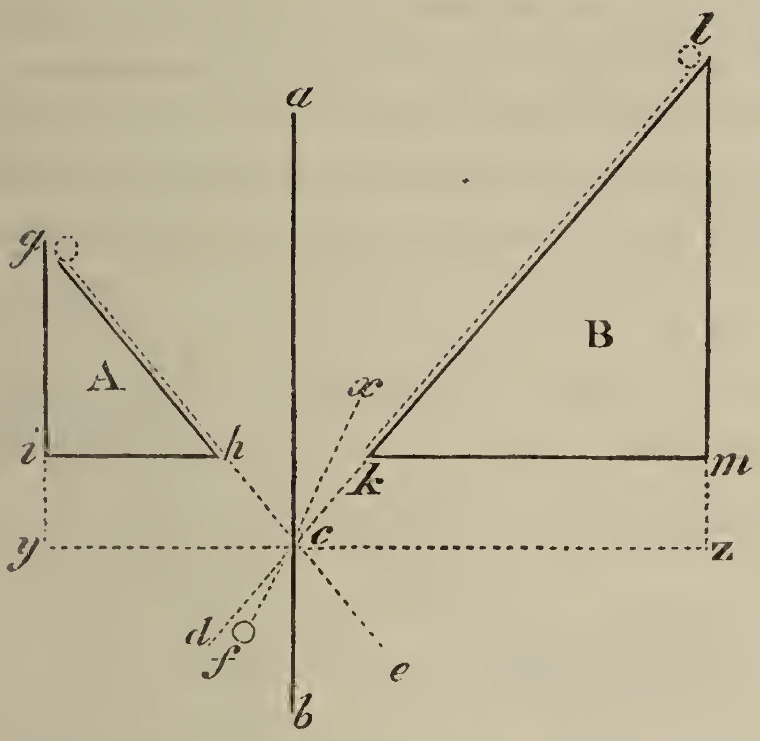
We have shewn above that there is a certain and constant nexus of particles of the magnetic element, extending from one pole to the other; and that one particle cannot, by reason of the mechanism of its figure, do otherwise than follow another in an orderly and as it were catenary sequence from the beginning of its motion to the end. Since therefore the situation of the particles is thus regular, it follows in the first place, that in the circle which crosses directly from one pole to the other, the particles are disposed conformably to this situation. Thus Fig. 84 (p. 99), let M be the north magnetic pole, and N the south magnetic pole; all the particles of the element which are in MN are in such a situation that one way they look to the north pole, another way to the south pole; that is to say, they conform to the tract or line of the circle MN; but in respect to a different meridian, or the polar meridian of the earth, the situation cannot be polar or rectilinear in relation to this meridian; but must be different, so that it is requisite that there should appear to be a certain declination of the needle.

Let us however enquire what occurs out of this circle in all other parts of the globe, and what situation of the particles of the magnetic element can be assigned upon mechanical principles, after it is known that there is a certain nexus of particles extending from one pole to the other. If we consult the science of geometry, as in a case of this kind we unquestionably ought, we shall find that they cannot have any other situation than such as is analogous to their distances on each side from the respective poles; and since there is a nexus and continual pressure of the particles from one pole to the other, the pressure at a less distance from the pole must be different from the pressure at a greater distance, and *vice versâ;* there is therefore an action upon the particles of this element according to the arcs or distances from the poles. But inasmuch as we must have two ratios in order to form a proportion, so we find in the present state of the particles, no other proportion than the one existing between the distances and angles; that is, as the distance or arc from one pole is to the distance or arc from the other pole, so is one angle to the other angle. We thus obtain the situation of the particles in every place, provided there be given the distances or arcs from the poles, and the angles formed by each with a given meridian. Or what amounts to the same, as the sum of the arcs or sides is to the sum of the angles, so is one arc or one side to the required angle. This proportion follows geometrically from the nexus and continual pression of the particles. Since we have thus the situation of the particles, we have consequently the declination of the needle, which is the same with the position of the particles; as we have above observed.

In this manner may be shewn the proportion of the sides and angles in the magnetic element. Every element exerts a pressure and acts proportionally to its altitude, as is the case with both water and air, and with all liquids; because one particle perfectly mobile and free pushes another equally and successively, in like manner as all do simultaneously. Altitude in this magnetic element cannot otherwise be conceived of than as extending from one pole to the other; from the north magnetic pole to the south, and *vice versâ;* nor can any other altitude be conceived as existing in this element; for it does not follow the laws of a perpendicular as do water and air, since this element is not governed by any other; hence it has no other element to press it to a perpendicular or horizontal position, or to keep it continually in a horizontal plane; for this element is the most subtile of all, nor can any other act upon its particles, because every other is of a grosser nature.

Consequently there cannot be any other altitude than the one pressing from pole to pole, nor any other pressure than the one acting altitudinally. In any given element there are two altitudes, as well as two active forces, or two pressures; one pressure or force which comes from one altitude of the element, another which comes from another altitude of the same element; and each pressure acts according to its altitude. If these pressures or forces meet, and if we would ascertain the direction which the fluid then takes, it will be in the ratio of the altitudes and angles. Thus Fig. 86, A and B are two oblique planes, one higher than the other; and if two equal little balls run obliquely down the planes, as in the larger B from *l* to *k*, then, according to the given direction acquired from

Fig. 86.*



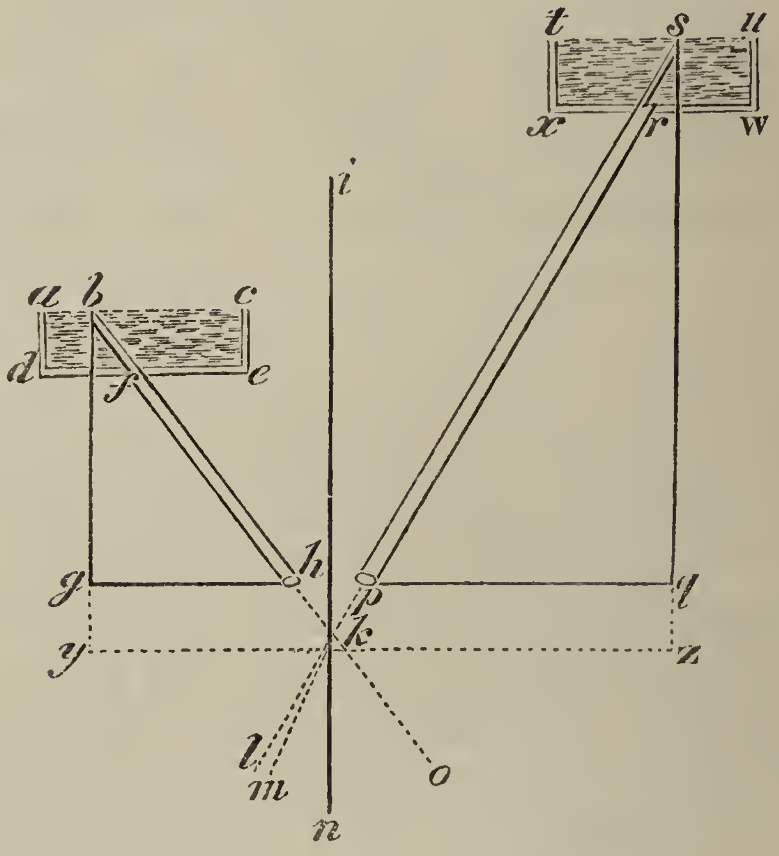
the plane, the ball will be carried toward *d;* unless by reason of its weight it begins to deflect its course into a parabola; a subject which is not here what we propose to consider, but merely the natural and simple directions. In like manner the ball *g,* flowing down the smaller plane to *h,* will tend in a right line to *e.* Suppose now these balls meet in *c,* (or the one which fell from the altitude *l* together with the one which fell from the altitude *g*), it is required to know the direction taken by the larger after it has met the smaller; and the answer is, that, according to the common rule of mechanics, as the sum of the altitudes *gy* and *lz* is to the sum of the angles *gca* and *lca,* so will the altitude *gy* be to the angle *lcx;* or, which is the same thing, the angle *dcf.* If therefore the required angle *dcf* be subtracted from the former given angle *dcb,* we obtain the angle or the line along which the ball takes its direction, namely, the line *cf.* Instead of the altitudes we may take the hypothenuses *lkc* and *ghc,* if the triangles are similar. The reason is known from the foregoing remarks. The force of the descending ball increases according to the altitude; therefore one ball descending from a higher altitude meets another with a force in the ratio of its altitude; while the other ball descending from a smaller altitude acquires a force according to this altitude; therefore when the two meet with their acquired forces, which are proportional to the altitudes, these forces will be to the directions as the altitudes to the angles.

---

* In the original, plate XXII., fig. 1.

Instead of two balls let us take the case of water; for water is an element, and it is of the nature of an element that we treat. Thus Fig. 87, let us conceive water at *txuw* and at *adce;* let siphons *rp* and *fh* from these receptacles descend obliquely to a horizontal plane; the altitude of one is *sz*, the altitude of the other is *by;* therefore because the pressure of the water is according to its altitude, let it be supposed that each stream meets in *k*, it is required to know the direction taken by the water. The same ratio prevails here as in the former case. The force of the water is as its altitude; each torrent therefore presses according to its altitude. The proportion is consequently as follows; as the sum of the altitudes or $sz+by$ is to to the sum of the angles or $ski+bki$, so is the altitude *by* to the angle *lkm;* whence we obtain the direction of the water.

Fig. 87.*

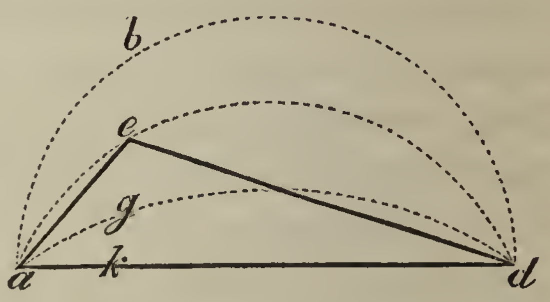


We have said that in the element of water, as also in air, these proportions are according to the altitudes; or that the pressure is according to the column of altitude. Now it being granted that the magnetic element exercises a pressure according to its altitude; that its altitude is to be estimated in the direction from one pole to the other; that each pole acts according to the side; why may not the altitude be conceived of as being according to the axis extending from one pole to the other? why should the altitude be reckoned according to circular lines or according to the surface of the earth's figure, and not according to its axis? In this case the altitude of the element we are considering would be similar to that of water and air, which passes directly from one pole to the other; it seems therefore as if the direction of the pressure ought to be calculated according to the altitudes in the axis; or what amounts to the same, according to the sines of the circle and not according to its arcs. It is replied, however, that this magnetic element, conformably to the contexture and ligation of its particles, presses indeed in an altitudinal direction, but not like water and air in a perpendicular, nor equally on all sides; for water and air press to the right and left, upwards, obliquely, and in every direction according to the altitude; but the magnetic element cannot press according to its altitude laterally, but only in the direction of its fluxion. In this appears to consist the difference of the pressure between the magnetic element and water or air. The reason is, that one particle of this element is colligated with another only in two places, namely, one at each pole; for, according to our principles as formerly laid down, every particle has its own pole. Since therefore one particle is connected with others only in two places, and the whole series thus coheres from one pole to another, it cannot act laterally or in other directions: it cannot act upon another according to its equator, or according to any other points of its figure or body. It acts therefore only in that direction in which it is capable of connexion with its proximate; or in which it can exert pressure; thus it cannot act like water or air. Consequently there can be a pressure and connexion of the particles only in that direction and only according to that altitude. Nor can there be any other altitude than the one according to which the particles are connected; that is to say, according to the arcs of the surface of the earth. Therefore the altitude of the magnetic element is according to the circle of the surface of the earth, and its force according to the arc of distance from the poles. Hence it follows, Fig. 88, if the magnetic element flow through the circle *abd*, that in *d* it exercises a pressure according to the arcs *ab* and *bd*; if it flow through another curve, as through *aed*, that in *e* it exercises a pressure according to the arcs *ae* and *ed*. The case is similar at *g*. If it flowed in a right line or along an axis such as *ad*, then at *k* it would press on both sides according to *ak* and *kd*. It may be asked still further, how it can be said that it exerts a pressure on both sides, and why there are as it were two altitudes and not one as in water? But inasmuch as the north pole of one particle is conjoined in like manner with the south pole of the other particle, and the south pole of the former with the north pole of the latter; and inasmuch as there is no difference between the conjunctions, there follow hence a pressure on each side and an altitude on each side.

---

* In the original, plate XXII., fig. 2.

Fig. 88.*



Let the place where the declination is to be observed, be in *c* (Fig. 89).† Let the meridian of this place be in *ah*; the north pole of the magnet in *b*; the south pole in *g*; the arc or distance of the place from one pole to the place of observation be *bc*; the arc or distance from the other pole *cg*; the angle of the meridian of the place of observation with the meridian of the south magnetic pole *gch*, or what is the same *acf*. Now in order to find the position of the particles of the magnetic element in this place, or what is the same, the declination, we must have recourse to the proportions thus furnished; namely, as the sum of the sides $(bc+cg)$ is to the sum of the angles $(bca+acf)$, so is the side *bc* to the angle *xcb*. If this angle *xcb* be subtracted from the angle before given or *bca*, we obtain the angle of the position of the particles of the magnetic element, or the angle of declination *xca;* and *xca* is thus the western declination of that place. A like method is pursued in regard to any other place of observation; as in Fig. 95 and 96, in the meridian *ach* in respect to which the north magnetic pole is in *b;* the south in *g;* where we have a proportion similar to the former; namely, as the sum of the sides ($bc+cg$), is to the sum of the angles ($bca+gch$), or what is the same, $bca+acf$, so is the side *bc* to the angle *bcx;* and if this latter *bcx* be subtracted from the given angle *bca,* we obtain the eastern declination of the place. It sometimes happens that each angle is on the same side of the meridian; in which case a like method of proportion must be adopted, but instead of the sum of the angles we must take the difference, and instead of substraction we must have recourse to addition, in order to obtain the declination. This however will be more clearly seen in the sequel.

---

* In the original, plate XXII., fig. 3.

† See the folding sheet at the end of this chapter and the note in the Appendix at the end of this volume.—*(Tr.)*

We shall now proceed to explain the method of calculating the declinations of the magnet in different places of the earth, and at different periods. But inasmuch as the calculation is tedious, and it is difficult at every stage in the several calculations to state the reasons of it and the diversities to which the calculation is subject; I have thought it better to give only a brief explanation of the particulars, and this too only in our first example; but sufficient to enable us to evince the truth both practically and theoretically.

CHAPTER XVI.

CALCULATION OF THE DECLINATION OF THE MAGNET FOR THE YEAR 1722, AT LONDON.

Inasmuch as the situation of the poles in relation to the meridian of London has been found by experiments for the year 1720, and the situation of the north magnetic pole relatively to the north pole of the earth to be 112° west, we have consequently first to add or subtract the angle between the London meridian and the meridian of the place where the declination is required. If the meridian of this place be distant from the London meridian 10° east, the angle must be added, thus; $112+10=122$; if it be distant 10° west, the angle must be subtracted, thus; $112-10=102$; for the meridian of the north magnetic pole is either near or remote, according to the nearness or remoteness of the meridian of the place of observation. Since however in our calculation we have assumed the meridian of London as our first meridian, there is in the present case no difference between the two meridians, and hence no necessity for any addition or subtraction.

We have next to ascertain the situation of the north magnetic pole for the given year, whether past or to come: in the present case, for the year 1722; and since the annual progression of the north pole in its own circle is nearly 56′, hence $1722-1720=2$, or a difference of two years; and $2\times 56'=1^\circ\ 52'$.

2. But since there is a progression of the north pole from west to east, we must take away from the given angle 1° 52′; and thus we obtain the situation of the pole for the required year,

as follows; 112°−1° 52′=110° 8′; whence the situation of the pole in respect to the London meridian for that year is 110° 8′.

3. We have next to ascertain the situation of these poles in the meridian of the place or the point of observation, where an arc drawn from them falls at right angles into the meridian. Thus in Fig. 91, where the north magnetic pole is in *b* and the north pole of the earth in *a*, we have to find where an arc from the former falls into the meridian at right angles, as at *zz*, for it is from this that we assume the terms for the subsequent calculations. We obtain then *zza* in the following trigonometrical manner. First, 110° 8′−90°=20° 8′, which is the same with the angle *zzba*. Hence we obtain *zza* trigonometrically thus: as the radius or *bzza* is to the side *ba*, so is the angle *abzz* to *zza*; or as the radius is to 22° 30′, so is 20° 8′ to *zza*=7° 34′. Or

Sine 22° 30′	958284
Sine 20° 8′	953682
	1911,966
Radius	10,00,000
Sine 7° 34′	911966

4. When the point where the north pole thus falls into the meridian is found, that is, where the arc from it falls into the meridian at right angles, we may then easily ascertain the distance of this point in the meridian from the place of declination; for we have only to add *zza* to the complement of the latitude of this place; or to subtract it if it be in *zz* as in Fig. 89, below the pole of the earth. Now since at London the altitude of the tellurian pole is 51° 32′, its complement is 38° 28′, which is equal to *ac*, Fig. 91. Therefore *zzc* is equal to 38° 28+′7° 34′=46° 2′.

5. The distance thus found or *zzc* is to be multiplied by 6″; thus 46° 2′×6″=4′ 36″. The reason of this calculation is, that as the magnetic element tends with a certain tacit current from the south pole to the north, its force is greatest at the south pole, and becomes gradually less toward the north, in the ratio of about one minute to every ten degrees, or six seconds to one

degree. Hence we must begin from the north pole and reckon towards the south. The greater the distance from the north pole, or the nearer to the south pole, the greater is the force; but toward the north pole it is less, and in the north pole itself it is only 22′ 30″. This addition or multiplication leads to the following calculations.

6. Since in the north pole there is a residuary force of 22′ 30″, obviously according to the distance of the magnetic poles from the poles of the earth, these minutes must be added to 22′ 30″. Thus 22′ 30″+4′ 36″=27′ 6″, which is the force in the place *c*, viz., London in the year 1722.

7. We have next to ascertain the distance of the poles in the same meridian; which is done by addition if the magnetic poles are above the poles of the earth, but by substraction if below them. In the present case the poles being above them, we have recourse to addition. The distance *zzyy* is required Fig. 91, and we obtain it thus: *zza*+*ah*+*hyy* or 180°+7° 34′ +18° 14′=205° 48′. In the sequel *hyy* will be seen to be equal to 18° 14′.

8. We must next proceed in a duplicate ratio. For instance, as the square of *ah* is to the square of *zzyy*, so are the minutes 27′ 6″ found in the point *b*, to some other number of minutes. Or, the square of 180 (=32400) is to the square 205° 48′ (=42400), as 27′ 6″ to 35′ 20″.

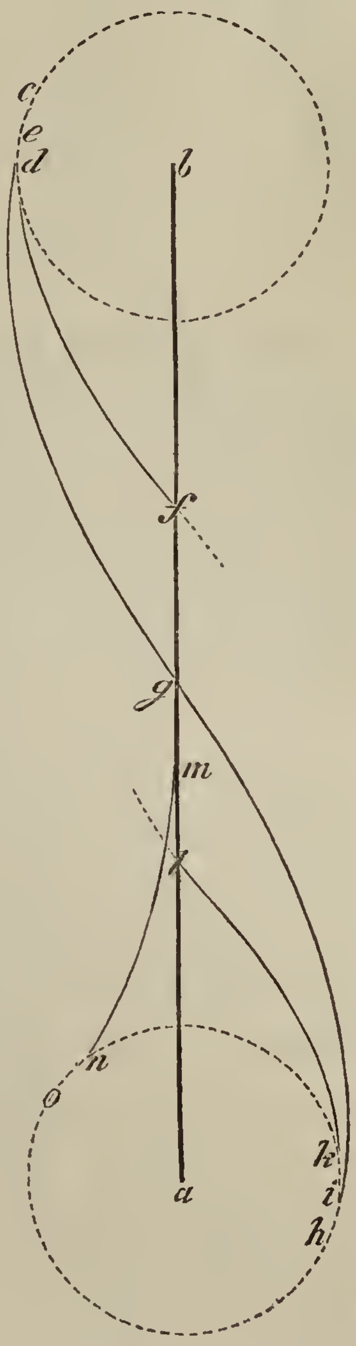
9. These minutes 35′ 20″ must be added to every tenth degree, beginning again from the north magnetic pole, or to every tenth degree of distance *zzc*; or must be multiplied decimally; 35′ 20″ × 46° 2′=2° 42′. We are thus supplied with the number 2° 42′ by which the distances of the poles and likewise the angles are to be diminished or increased, which is done partly on account of the force and current of the magnetic element from the south pole to the north, and partly on account of the spiral flow and pressure of this element.

10. The number 2° 42′ must now be added to the genuine side or true distance of the poles 22° 30′, so that this side which is to be used in our calculation, and which we therefore call the *latus calculi*, is 22° 30′+2° 42′=25° 12′. For we cannot reckon with the simple distance 22° 30′. If however there were no force tending from the one pole to the other and no tension or effort,

nor any spiral figure in the fluxion, then we should simply use the distance 22° 30′. But as these anomalies disturb the calculation, so it cannot be carried on without the augmentation of the sides or distances in the way above mentioned. Thus the distance or other *latus calculi* may be found, which in the present case is 25° 12′, and this at each pole.

11. Inasmuch however as the spiral fluxion of the element disturbs the angles, so that the pole cannot appear in its own true and natural place, but in some other by reason of the spiral flexure, the angle requires to be varied and transposed. Hence if the north pole be in *c* (Fig. 97), and the south in *h*, as the element flows spirally from one pole to another, near the pole the contorsion and flexure of the spire is greater, and farther off it is less; whence if the pole be in *c* and the place of observation in *f*, the pole appears by reason of the spire to be in *d*, or in *k* if the place of observation be in *l*. Inasmuch therefore as the spire at the south pole runs from west to east and at the north pole likewise towards the east, the degrees at the north pole must be taken away, or the angle diminished; and when this pole is in *c* it must be transposed into *d*. At the south pole if it be in *h* it must be transposed into *k*. Or if it be on the other side of the south pole, as in *n*, and the place of observation be in *m*, the angle of the pole must be transposed in the way we have mentioned from west to east, or from *n* to *o*, and so forth. Let the degrees found in the ninth clause, or 2° 42′, be first subtracted from the true angle in the second clause, namely, 110° 8′, and then there remains the angle 107° 26′, which is the one to be adopted in the calculation, and which we there-

Fig. 97.*



---

* In the original, plate XXIII., fig. 1.

fore denominate the *angulus calculi,* but which must be proportioned still further in a ratio to the distances from the pole.

12. Inasmuch however as the nearer to the pole the greater is the inflection of the spire, and the farther from the pole the less, the angle must again be subjected to another proportion, namely, to the distance from the pole; and hence I have prepared a table from which the proportions may be taken for every degree of latitude.

Lat. of the North or South Pole.	Proportions to be used in the Calculation.		Lat. of the North or South Pole.	Proportions to be used in the Calculation.	
Deg.	Deg.	Min.	Deg.	Deg.	Min.
10	0	2½	40	40	—
15	0	5½	45	50	—
20	10	—	50	61½	—
25	15½	—	55	74½	—
30	21	—	60	90	—
35	30¼	—	67 : 30′	112	30

This table is formed in the following manner. I assume as a basis 90, at which, or at a distance of 90° from the pole, the translation of the angles vanishes, and I have taken the least and greatest distance of the magnetic pole. Then proceeding in a duplicate ratio thus: since the least distance is 67° 30′ or 90°−22° 30′=67° 30′, and the greatest distance 112° 30′ or 90°+22° 30′=112° 30′, as the square of 67° 30′ or 4556° is to 112° 30′ so is the square of 10, 20, 30, 40, 50, 60, &c., to the number, 2½, 5½, 10, 15½, 21, as found in the table. Since therefore the number 2° 42′ is already obtained by the multiplication of 60, or at a latitude of about 49, we must by a further proportion discover the other number, by which the angle is diminished that is made by the north and south poles. The latitude of the pole at London is 51° 32′, and the number corresponding to this latitude is 66½ or 67. We must then proceed thus: 60° : 67°::2° 42′ : 3° 1′. Thus 3° 1′ is the true number at this latitude which is to be subtracted from the original angle at the north, which was 110° 8′. Hence 110° 8′−3° 1′=107° 7′. Whence the angle 107° 7′ is the angle of the calculus as changed from the former, or 110° 8′, and transposed in consequence of the spiral fluxion of the element.

We have thus the *latus calculi* at the north pole=25° 11′;

and the *angulus calculi* at the same pole = 107° 7′. The complement of which is 72° 53′.

13. These particulars being ascertained, we have next to find the sides and angles *bc* and *bca*. (Fig. 92.)

We have first to find the side *dc*, which is done by the following process in spherical trigonometry. As the radius is to the sine *ac* (= 38° 28′ or the complement of the latitude), so is the sine *dac* (= 72° 53′ or the complement of the angle of the meridians 107° 7′ to the semicircle) to the sine *dc* = 36° 28′. By logarithms thus;

Sine 38° 28′	979383
Sine 72° 53′	998032
	1977415
Radius	10,00000
Sine 36° 28′	977415

The side *dc* therefore = 36° 28′. It is to be observed that the angle *ad* ought to be a right angle.

14. We next proceed to find the side *da* as follows. As the tangent to the complement *ac* (= 38° 28′) is to the whole sine, so is the sine of the complement *cad* (= 72° 53′) to the tangent *ad* (13° 10′). Trigonometrically thus;

Sine to comp.	72° 53′	946881
Radius		10,00000
		1946881
Tang. to comp.	38° 28′	10,09991
Tang.	13° 10′	936890

Therefore *ad* is equal to 13° 10′.

15. We have next to find the side *bc* between the north magnetic pole and the place of observation. We have in the triangle *bdc* the two sides *bd* and *dc*, together with the included right angle *bdc*. But in order to obtain *bd*, we must add *ba* and *ad*. In the present case *ba* = 25° 12′, and is the same with the *latus calculi*, namely, 25° 12′ + 13° 10′ = 38° 22′. Again *bc* is

found thus. As the radius is to the sine of the complement *dc* (=36° 28′), so is the sine of the complement *db* (=38° 22′) to the sine of the complement *bc* (=50° 54′). Logarithmically thus;

Sine to comp. 36° 28′	990536
Sine to comp. 38° 22′	989434
	1979970
Radius	10,0000
Sine to comp. 50° 54′	979970

We have thus the side at the north, or *bc*=50° 54′.

16. We have next to find the angle *bca*, which is done simply by means of the sines; for the three corresponding sines of the triangle *bac* are given. Thus as the sine *bc* (=50° 54′) is to the sine *bac* (=72° 53′ or the complement of the angle 107° 7′), so is the sine *ba* (=25° 12′) to the sine *bca* (=31° 37′). Trigonometrically thus;

Sine 25° 12′	962918
Sine 72° 53′	998032
	1960950
Sine 50° 54′	988988
Sine 31° 37′	971962

We have thus the angle *bca*=31° 37′.

17. Let us now advert to the south pole, and in like manner ascertain the sides and angles there. In the first place must be added or subtracted the angle between the meridian of London and the meridian of the place where the declination is required. But inasmuch as in our present calculation the first meridian is assumed to be at London, there is no difference of meridians, and consequently no need of addition or subtraction.

We have next to ascertain the position of the south magnetic pole for the given year, in the present case for the year 1722. Inasmuch as the annual progression of the south pole in its own circle is nearly 20′, hence 1722−1720=2, or there is a difference of two years, which multiplied by 20′=40′.

18. Inasmuch as the progression of the south pole is from west to east, we are hence to take away 40′ in order to arrive at the situation of the pole for the required year 1722, which is done as follows: 145° 30′ − 0′ 40′ = 144° 50′. Hence the situation of the pole in respect to the London meridian for that year is 144° 50′.

19. We have next to enquire into the situation of the pole in the meridian of the place, or the point where an arc from it falls at right angles into the meridian, as in Fig. 92. Let the south pole of the earth be in *h*; the south magnetic pole in *g*; we have to ascertain where an arc from the latter falls at right angles into this meridian as in *yy*. Now *yyh* is obtained in the following trigonometrical manner. First 144° 50′ − 90° = 54° 50′, which is the same with the angle *yygh*; whence we obtain *yyh* trigonometrically thus. As the radius *gyyh* is to the side *gh*, so is the angle *hgyy* to the side *hyy*. Or in numbers, thus; as the radius is to 22° 30′ so is 54° 50′ to *yyh* = 18° 14′.

Sine 22° 30′	958284
Sine 54° 50′	991247
	1949531
	10,00000
Sine 18° 14′	949531

20. We have next to ascertain the distance of this pole in the meridian from the place of observation, or *yyc*, which is done in the following manner by adding the sides to each other, viz.;—*hyy*, and then 90°, or the side from *h* to the equator, and then the latitude, or distance from the equator to the place of observation; thus, 18° 14′ + 90° + 51° 32′ = 159° 46′, the complement of which is 20° 14.′ This complement is obtained in a better way, by subtracting the side *hyy* when found from the complement of the latitude, thus; 38° 28′ − 18° 14′ = 20° 14′.

21. It is from this place that the ensuing calculation must be commenced, because it is distant from the pole 180°; and as in clause 9, so here also the minutes 35′ 20″, as found in clause 8, must be multiplied decimally into the distance 20° 14′, thus;

$35' \, 20'' \times 20^\circ \, 14' = 1^\circ \, 11'$; the reason of which is specified in clause 9.

22. But inasmuch as nearer to the pole the inflection of the spire is greater, and farther off it is less, the angle must be proportioned to the inflection of the spire, or to its distance from the pole. Hence the reader is referred to the table in clause 12, where for the latitude of London we find the ratio 60 to 67, as we have said. Therefore $60 : 67 :: 1^\circ \, 11' : 1^\circ \, 19'$.

In order to obtain the northern angle of the calculus, we must add 1° 19′ to the true angle, as follows; $144^\circ \, 50' + 1^\circ \, 19' = 146^\circ \, 9'$. The reason of this may be seen in clause 12. The southern angle of the calculus is therefore 146° 9′, and its complement 33° 51′.

23. We have next to enquire for the side *gc* and the angle *gch*, as in the corresponding case of the north pole. In the first place let the side *gh* (Fig. 94) be produced to *n*, where the arc *cn* falls at right angles into *n*. Then as the radius or angle *cnh* is to the sine *hc* (or its complement to 180°, which is equal to $38^\circ \, 28' = ac$), so is the sine *dac* ($= 33^\circ \, 51'$, or the complement of 146° 9′ to 180°, which is the angle at the south pole) to the sine *cn* ($= 20^\circ \, 16'$). By the logarithms of the sines thus;

Sine 38° 28′	979383
Sine 33° 51′	974587
	1953970
Radius	10,00000
Sine 20° 16′	953970

We have thus the arc $cn = 20^\circ \, 16'$.

24. In the next place we have to find *nh*; as follows. The tangent to the complement $ch = 38^\circ \, 28'$. Or as *ch* the complement to the semicircle is to the radius, so is the sine of the complement *chn* ($= 33^\circ \, 51'$) to the tangent *nh* ($= 33^\circ \, 25'$). By logarithms thus;

Sine to compl.	33° 51′	991934
Radius		10,00000
		1991934
Tang. comp.	38° 28′	10,09991
Tang.	33° 25′	981943

We thus obtain nh, if 33° 25′ be subtracted from 180°; but in our calculation we must use only 33° 25′.

25. We must proceed to ascertain the south side gc in the following manner. As the radius is to the sine of the complement nc (=20° 16′), so is the sine of the complement ng (=8° 13′) to the south side required (=21° 48′), or to the complement of 158° 12′ to 180°. But it is to be observed that ng is equal to 8° 13′, for this reason; viz., nh=146° 35′, or its complement is 33° 25′. If to this be added hg=25° 12′, we have the whole side=171° 47′; if this be subtracted from the semicircle so as to obtain the complement, there remain 8° 13′, which is the sum to be used in the calculation. By logarithms thus;

Sine comp. 20° 16′	997224
Sine comp. 8° 13′	999552
	1996776
Radius	10,00000
Sine comp. 21° 48′	996776

In order to obtain gc, we must take the complement of 21° 48′ to the semicircle, which is 158° 12′.

26. We have next to ascertain the angle gch, which is done by sines in the following manner. As the sine gc=21° 48′ (for we must use the complement of 158° 12′ to the semicircle) is to the sine chg=33° 51′ (for we must use the complement of the angle chg=146° 9′), so is the sine hg (=25° 12′) to the angle gch (=39° 41′). Trigonometrically thus;

Sine 25° 12′	962918
Sine 33° 51′	974587
	1937505
Sine 21° 48′	956980
Sine 39° 41′	980525

We have thus the angle gch=39° 41′, as also the side gc= 158° 12′.

27. We have thus the two sides and the two angles required; namely, the side $bc = 50^\circ\ 54'$; the angle $bca = 31^\circ\ 37'$. In like manner the south side $hc = 158^\circ\ 12'$; the angle $hcg = 39^\circ\ 41'$. Having obtained these sides and angles, we proceed proportionally thus. As the sum of the sides $bc + cg$ ($= 50^\circ\ 54' + 158^\circ\ 12' = 209^\circ\ 6'$) is to the sum of the angles or $bca + gch$ ($= 31^\circ\ 37' + 39^\circ\ 41' = 71^\circ\ 18'$), so is the north side bc ($= 50^\circ\ 54'$) to the angle bcx ($= 17^\circ\ 14'$). Or more clearly thus;

$$\begin{array}{ll} 50^\circ\ 54' & 31^\circ\ 37' \\ 158^\circ\ 12' & 39^\circ\ 41' \\ \hline 209^\circ\ \ 6'. & 71^\circ\ 18' :: 50^\circ\ 54' : 17^\circ\ 14. \end{array}$$

28. Let the angle bcx ($= 17^\circ\ 14'$) be subtracted from the angle $bca = 31^\circ\ 37'$), and there remains the angle $xca = 14^\circ\ 23'$, which is the same with the declination of the needle at London in the year 1722.

According to the observations of Mr. Graham, instituted at London, on March 8, 1722, the declination was 14° 22′; according to our present calculation it was 14° 23′, a difference of only one minute.

In consequence of the anomalies which occur in the motion of the magnetic element, its tendency from one pole to another, and its spiral pressure and fluxion, we cannot use a shorter and more easy calculus; and although the process may appear laborious, yet by practice it becomes familiar. In the following examples therefore our explanations will be more brief and succinct, which will make the calculation appear not quite so prolix and circuitous.

II.

Calculation of the Magnetic Declination for the year 1700, *at London.*

Its latitude is 51° 32′ north, of which the complement is 38° 28′.

1) Between 1720 and 1700 there are 20 years intervening, whence $20^\circ \times 56' = 18^\circ\ 40'$.

2) $112^\circ\ 0' + 18^\circ\ 40' = 130^\circ\ 40'$.

3) $130^\circ\ 40' - 90 = 40^\circ\ 40'$.

Sin. 22° 30′ 958284.
Sin. 40° 40′ 981402.

Sin. 14° 26 939686. for *pa;*

4) For the south angle, mul-

tiply as above 20° years by 20′, or 20° × 20′ = 6° 40′.

5) 145° 30′ + 6° 40′ = 152° 10′.

6) 152° 10′ − 90 = 62° 10′.

Sin. 22° 30′ 958284.
Sin. 62° 10′ 994660.
———
Sin. 19° 47′ 952944 for *oh*.

7) 38° 28′ + 14° 26′ = 52° 54′, or *pc*.

8) 52° 54′ × 6″ = 5′ 18″.

9) 22′ 30″ + 5′ 18″ = 27′ 48″.

10) 180° + 14° 26′ + 19° 47′ + 214° 13′, or *po*.

11) As the square of 180° = 32400 is to the square of 214° 13′ = 45800, so is 27′ 48″ to 40′.

12) 40′ in 52° 54′ = 3° 32′, by decimal calculation; or 40′ in 5, 2° = 54′.

13) 22° 30′ + 3° 32′ = 26° 2′, which is the same as the side or distance of the two poles to be used in the calculation; or *ba* and *hg*.

14) 60 : 67 :: 3° 32′ : 3° 57′; therefore 130° 40′ − 3° 57′ = 126° 43′, which is the angle *cab*, to be used in the calculation: its complement is 53° 17′.

15) For *cd*;
Sin. 38° 28′ 979383.
Sin. 53° 17′ 990395.
———
Sin. 29° 54′ 969778.

16) For *ad*;
Sin. compl. 977659 − 53° 17′.
Radius 10,00000.
———
1977659
Tang. comp. 10,09991 − 38° 28′.
———
Tangent 967668 − 25° 24′.

17) For *bc*; *bd* = *ba* + *ad*, or 25° 24′ + 26° 2′ = 51° 26′.
Sin. compl. 29° 54′ 993796.
Sin. compl. 51° 26′ 979478.
———
Sin. compl. 57° 17′ 973274.

18) For the angle *bca* there will be the proportion 57° 17′ : 53° 17′ :: 26° 2′ : 26° 2′, or
Sine 26° 2′ 964236.
Sine 53° 17′ 990396.
———
1954632.
Sine 57° 17′ 992497.
———
Sine 24° 43′ 962135, for *bca*.

Thus we have the side *bc* = 57° 17′, and the angle b*ca* = 24° 23′. Now for the south side and angle.

19) 38° 28′ − 19° 47′ = 18° 41′, for the complement of the side *oc*.

20) By decimal calculation 40′ in 18° 41′ = 1° 15′.

21) For its increase; 60° : 67° :: 1° 15′ : 1° 24.′

22) 1° 24′ must be added to the south angle, or 152° 10′ + 1° 24′ = 153° 34, which is the south angle of the calculus: its complement is 26° 26′.

23) For *nc*;
Sine 38° 28′ 979383.
Sine 26° 26′ 964851.
———
Sine 16° 5′ 944234, or *nc*

24) For *nh*;
Sine of compl. 26° 26′ 995204.
Radius 10,00000.
———
1995204.
Tang. to compl. 38° 28′ 10,09991.
———
Tangent 35° 26′ 985213.

25) For the side *gc* first subtract 35° 26′−26° 2′=9° 24′.

Sine of compl. 16° 5′ 998266.
Sine of compl. 9° 24′ 999413.

Sine of compl. 18° 34′ 997679.

Its complement gives the side *cg*=161° 26′.

26) For the angle *gch* we shall have the proportion, as 18° 34′ to 26° 26′, or compl. of angle 153° 24′, so 26° 2′, or the side of the calculus, to 37° 58′, the angle required.

Sine 26° 2′ 964236.
Sine 26° 26′ 964851.

1929087.
Sine 18° 34′ 950298.

Sine 37° 58′ 978889.

Thus we have the side *gc*=161° 26′; and the angle *gch*=37° 58′.

	Sides.	Angles.
27)	57° 17′	24° 43′
	161° 26′	37° 58′

218° 43′ : 62° 41′ :: 57° 17′ : 16° 29′.

28) If 16° 29′ be subtracted from the angle 24° 43′, there remains declination west 8° 14′.

According to observations made at London in the year 1700, the declination was 8° 0′, making therefore a difference of 0° 14′.

III.

Calculation of the Magnetic Declination for the year 1692, *at London.*

Its latitude is 51° 32′ north; its compl. 38° 28′.

1) Between 1700 and 1692 intervene 28 years; hence 28×56′ =26° 8′.

2) 112° 0′+26° 8′=130° 8′, the true north angle.

3) 138° 8′−90=48° 8′, for *pa*.

Sine 22° 30′ 958284.
Sine 48° 8′ 987198.

Sine 16° 33′ 945482.

4) For the south angle+28×20′=9° 20′.

5) 145° 30′+9° 20′=154° 50′, the true south angle.

6) For *oh*;
154° 50′−90°=64° 50′, then
Sine 22° 30′ 958284.
Sine 64° 50′ 995668.

Sine 20° 16′ 953952.

7) For *pc* we have 38° 28′+16° 33′=55° 1′.

8) 55° 1′×6°=5′ 30″.

9) 22′ 30″+5′ 30″=28′ 0″.

10) For *po*;
180+16° 33′+20° 16′=216° 49′.

11) The square of 180°=32400, is to the square of 216° 49′=47000, as 28′ to 40′ 37″.

12) By decimal calculation; 40′ 37″×55° 1′=3° 43′.

13) $22^\circ\ 30'+3^\circ\ 43'=26^\circ\ 13'$, the side of the calculus.

14) For the increase of the angle of the calculus; $60 : 67 :: 3^\circ\ 43' : 4^\circ\ 9'$.

Subtract this from the true angle, or $138^\circ\ 8'-4^\circ\ 9'=133^\circ\ 59'$. Thus the angle of the calculus is 133° 59′, the complement of which is 46° 1′.

15) For *cd*;

Sine 38° 28′ 979383.
Sine 46° 1′ 985705.

Sine 26° 35′ 965088.

16) For *ad*;

Sine of complement 46° 1′, and rad. 1984164
Tang. to comp. 38° 28′ 10,09991

Tangent 28° 53′ 974173

17) For *bc*; $bd=ba+ad$, or $28^\circ\ 53'+26^\circ\ 13'=55^\circ\ 6'$.

Sine of compl. 26° 35′ 995147.
Sine of compl. 55° 6′ 975750.

Sine of compl. 59° 14′ 970897.

18) For angle *bca* we shall have the proportion $59^\circ\ 14' : 46^\circ\ 1' :: 26^\circ\ 13' : 21^\circ\ 43'$, or

Sine 26° 13′ 964519.
Sine 46° 1′ 985705.

1950224.
Sine 59° 14′ 993412.

Sine 21° 43′ 956812.

Thus we have the side $bc=59^\circ\ 14'$, and the angle $bca=21^\circ\ 43'$. Let us now find the side and angle at the south pole.

19) $38^\circ\ 28'-20^\circ\ 16'=18^\circ\ 12'$, for the complement of the side *oc*.

20) By decimal calculation, $40'\ 37''\times 18^\circ\ 12'=1^\circ\ 13'$.

21) The increase for that latitude; $60 : 67 :: 1^\circ\ 3' : 1^\circ\ 21'$.

22) Add 1° 21′ to the true south angle, that is to say, $154^\circ\ 50'+1^\circ\ 21'=156^\circ\ 11'$, and 156° 11′ is the south angle of the calculus, and 23° 49′ its complement.

23) For *nc*;

Sine 38° 28′ 979383.
Sine 23° 49′ 960617.

Sine 14° 33′ 940000.

24) For *nh*;

Sine of compl. 23° 49′, and Rad. 19,96134.
Tang. to compl. 38° 28′ 10,09991.

Tang. 36° 1′ 986143.

25) For the side *gc*; $36^\circ 1'-26^\circ\ 13'=9^\circ\ 48'$.

Sine of compl. 14° 33′ 998584.
Sine of compl. 9° 48′ 999361.

Sine of compl. 17° 29′ 997945.

Its complement gives the side $cg=162^\circ\ 31'$.

26) For the angle *gch*, we shall have the proportion; as 17° 29′ to 23° 49′, or to the complement of the south angle of the calculus, so 26° 13′, or the side of the calculus, to 36° 25′, or the angle required. By logarithms:

Sine 26° 13′ 964519.
Sine 23° 49′ 960617.

1925136.
Sine 17° 29′ 947774.

Sine 36° 25′ 977362.

Thus we have the side gc=162° 31′, and the angle gch=36° 25′.

	Sides.	Angles.
27)	59° 14′	21° 43′.
	162° 31′	36° 25′.
	221° 45′	58° 8′

221° 45′ : 58° 8′ :: 59° 14′ : 15° 28′.

28) Subtract 15° 28′ from the angle 21° 43′, and there remains declination west 6° 15′.

According to observations it was 6° 8′, giving a difference of 0° 15′.

IV.

Calculation of the Magnetic Declination for the year 1735, *at London.*

Its latitude is 51° 32′ north; its complement 38° 28′.

1) Between 1720 and 1735 intervene 15 years, hence 15° × 56′ = 14°.

2) 112° 0′ − 14° 0′ = 98° 0′.

3) For *pa*;
98° 0′ − 90° = 8° 0′.
Sine 22° 30′ 958284.
Sine 8° 0′ 914355.

Sine 3° 3′ 872639.

4) For the true south angle, multiply as above 15 years by 20′, or 15 × 20′ = 5° 0′; therefore

5) 145° 30′ − 5° 0′ = 140° 30′, which is the true south angle.

6) For *oh*;
140° 30′ − 90 = 50° 30′.
Sine 22° 30′ 958284.
Sine 50° 30′ 988740.

Sine 17° 10′ 947024.

7) For *pc*; 38° 28′ + 3° 3′ = 41° 31′

8) 41° 31′ × 6″ = 4′ 9″.

9) 22′ 30″ + 4′ 9″ = 26′ 39″.

10) For *po*,
180° + 3° 3′ + 17° 10′ = 200° 13′.

11) The square of 180 = 32400 : the square of 200° 13′ = 40050 :: 26′ 39″ : 33′.

12) By decimal calculation, 33′ × 41° 31′ = 2° 17′.

13) 22° 30′ + 2° 17′ = 24° 47′, which is the side of the calculus.

14) For the increase of the angle of the calculus; 60 × 67 :: 2° 17′ : 2° 33′. 98° 0′ − 2° 33′ = 95° 27′, and 97° 27′ is the north angle of the calculus, of which the complement is 84° 33′.

15) For *cd*;
Sine 38° 28′ 979383.
Sine 84° 33′ 999803.

Sine 38° 15′ 979186.

16) For *ad*;
Sine compl. 84° 33′ 1897762.
Tang. compl. 38° 28′ 10,09991.

Tangent 4° 19′ 887771.

17) For *bc*; $bd = ba + ad$ = 24° 47′ + 4° 19′ = 29° 6′.
Sine compl. 38° 15′ 989504.
Sine compl. 29° 6′ 994139.

Sine compl. 46° 40′ 983643.

18) For the angle *bca* there will be the proportion, 46° 40′ : 84° 33′ :: 24° 47′ : 35° 0′; or

Sine 24° 47′ 962241.
Sine 84° 33′ 999803.

1962044.
Sine 46° 40′ 986175.

Sine 35° 0′ 975869.

Thus we have the side *bc*=46° 40′, and the angle *bca*=35° 0′.

We must now find the side and angle at the south pole.

19) 38° 28′−17° 10′=21° 18, for the complement of the side *oc*.

20) By decimals 33′×21° 18′ =1° 9′.

21) For the increase at that latitude 60 : 67 :: 1° 9′ : 1° 17′.

22) Add 1° 17′ to the true south angle, that is to say, 140° 30′+1° 17′=141° 47′. And thus 141° 47′ is the true southern angle of the calculus; its complement is 38° 13′.

23) For *nc;*

Sine 38° 28′ 979383.
Sine 38° 13′ 979143.

Sine 22° 38′ 958526.

24) For *nh;*

Sine of compl. 38° 13′ 1989524.
Tang. compl. 38° 28′ 10,09991.

Tang. 31° 58′ 979533.

25) For the side *gc;* 31° 58′−24° 47′=7° 11′.

Sine of compl. 22° 38′ 996519.
Sine of compl. 7° 11′ 999657.

Sine of compl. 23° 42′ 996176.

Its complement gives the side *cg*=156° 18′.

26) For the angle *gch* there will be the proportion 23° 42′ : 38° 13′ :: 24° 47′ : 40° 10′. By the logarithms of the sines:

Sine 24° 47′ 962241.
Sine 38° 13′ 979143.

1941384.
Sine 23° 42′ 960417.

Sine 40° 10′ 980967.

Thus we have the side *gc*=156° 18′, and the angle *gch*=40° 10′.

	Sides.	Angles.
27)	46° 40′	35° 0′
	156° 18′	40° 10′

203° 8′ : 75° 10′ :: 46° 40′ : 17° 14′.

28) If 17° 14′ be subtracted from 35° 0′, there remains the declination west 17° 46′.

V.

Calculation of the Magnetic Declination for the year 1610, *at Paris.*

The latitude of the Pole is 48° 51′. Its complement 41° 9′.

Longitude east from London 2° 25′.

1) Between 1610 and 1720 intervene 110 years: hence 110°×56′=102° 40′.

2) Add these degrees together

with the east longitude 2° 25′, to the north angle; 112+102° 40′+2° 25′=217° 5′; which subtracted from 360 leaves 142° 55′ to the east; and 142° 55′ is the true north angle.

3) For *pa;*

142° 55′−90=52° 55′.

Sine 22° 33′ 958284.

Sine 52° 55′ 990187.

Sine 17° 46′ 948471.

4) For the south angle, 110°×20′=36° 40′.

5) Add these angles, together with the east longitude; namely, 145° 30′+36° 40′+2° 25′=184° 35′; which subtracted from 360, leaves 175° 25′, the true south angle towards the east.

6) For *oh;*

175° 25′−90=85° 25′.

Sine 22° 30′ 958284.

Sine 85° 25′ 999860.

Sine 22° 25′ 958144.

7) For *pc;*

41° 9′+17° 46′=58° 55.′

8) 58° 55′×6″=5′ 54″.

9) Hence 22′ 30″+5′ 54″=28′ 24″.

10) For *po;*

180°+17° 46′+22° 25′=220° 13′.

11) The square of 180°=32400: the square of 220° 13′=48400, :: 28′ 24″ : 42′ 26″.

12) By decimal calculation; 42′ 26″×58° 55″=4° 10′.

13) 22° 30′+4° 10′=26° 40′, and 26° 40′ is the apparent side of the calculus.

14) For the increase at this latitude may be considered as none; for the ratio would be as 60 to 59½: but add 4° 10′ to the true north angle 142° 55′; that is to say, 142° 55′+4° 10′=147° 5′ towards the east; its complement is 32° 55′.

15) For *cd;*

Sine 41° 9′ 981824.

Sine 32° 55′ 973523.

Sine 20° 57′ 955347.

16) For *ad;*

Sine compl. 32° 55′ and

Rad. 1992400.

Tang. compl. 41° 9′ 10,05854.

Tang. 36° 16′ 986546.

17) For *bc*; *bd*=*ba*+*ad*, or 26° 40′+36° 16′=62° 56′.

Sine compl. 20° 57′ 997029.

Sine compl. 62° 56′ 965803.

Sine compl. 64° 51′ 962832.

18) For the angle *bca* there will be the proportion 64° 51′ : 32° 55′ :: 26° 40′ : 15° 38′.

Sine 26° 40′ 965205.

Sine 32° 55′ 973523.

1938728.

Sine 64° 51′ 995674.

Sine 15° 38′ 943054.

Thus we have the side *bc*=64° 51′, and the angle *bca*=15° 38′.

We must now find the side and angle at the south pole.

19) For the complement of the side *oc;* 41° 9′−22° 25′=18° 44′.

20) By decimal calculation 42′ 26″×18° 44′=1° 20′.

21) There is no need here of any increase of the angle.

22) Subtract 1° 20′ from the true south angle; that is, 175° 25′−1° 20′=174° 5′; and 174° 5′ is the apparent angle of the calculus towards the east: its complement is 5° 55′.

23) For *nc;*

Sine 41° 9′ 981824.
Sine 5° 55′ 901318.

Sine 3° 53′ 883142.

24) For *nh;*

Sine compl. 5° 55′, and
Rad. 1999768.
Tang. compl. 41° 9′ 10,05854.

Tangent 41° 0′ 993914.

25) For the side *gc;* 41° 0′−26° 40′=14° 20′.

Sine compl. 3° 53′ 999900.
Sine compl. 14° 20′ 998626.

Sine compl. 14° 51′ 998526.

Its complement gives the side *cg*=165° 9′.

26) For the angle *gch* there will be this proportion; 14° 51′ : 5° 55′ :: 26° 40′ : 10° 24′, or as the side sought, 14° 51′, to the complement of the apparent angle of the calculus; so is 26° 40′, or the side of the calculus, to the angle in question. By sines:

Sine 26° 40′ 965205.
Sine 5° 55′ 901318.

1866523.
Sine 14° 51′ 940873.

Sine 10° 24′ 925650.

	Sides.	Angles.
27)	64° 51′	15° 38′
	165° 9′	10° 24′

230° 0′ : 26° 2′ :: 64° 51′ . 7° 20′.

28) If 7° 20′ be subtracted from 15° 38′, there remains the declination east 8° 18′.

According to observations made in that year, the declination was 8° 0′ towards the east; leaving a difference of 0° 18′.

VI.

Calculation of the Magnetic Declination for the year 1620, *at Paris.*

North latitude 48° 51: its complement 51° 9′.

Longitude east from London 2° 25′.

1) Between 1620 and 1720 intervene 100 years: hence 100 ×56′=93° 20′.

2) Add these degrees 93° 20′, together with the longitude or distance of the meridians, to 112° 0′; or thus, 112° 0′+2° 25′+93° 20′ =207° 45′; which subtracted from 360° leave 152° 15′, the true north angle towards the east.

3) For *pa;*
152° 15′−90°=62° 15′.
Sine 22° 30′ 958284.
Sine 62° 15′ 994693.

Sine 19° 47′ 952977.

4) For the south pole multiply as above; or 100×20′=33° 20′.

5) Add these degrees, together with the distance of the longitude, to the south angle 145° 30′; that is, 145° 30′+33° 20′+2° 15′=181° 15′, which subtracted from 360° leaves 178° 45′, the true south angle towards the east.

6) For *oh;*
178° 45′−90°=88° 45′.
Sine 22° 30′ 958284.
Sine 88° 45′ 999989.

Sine 22° 30′ 958273.

7) For *pc;*
41° 9′+19° 47′=60° 56′.

8) 60° 56′×6″=6′ 6″.

9) Hence 22′ 30″+6′ 6″=28′ 36″.

10) For *po;*
180° 0′+19° 47′+22° 30′=222° 17′.

11) The square of 180°=32400 is to the square of 222° 17′=49300, as 28′ 36″ to 43′ 18″.

12) By decimal calculation 43′ 18″×60° 56′=4° 23′.

13) 22° 30′+4° 23′=26° 53′; and thus 26° 53′ is the apparent side of the calculus.

14) There is no need here of any increase: add 4° 23′ to the true north angle thus; 152° 15′+4° 23′=156° 43′; and 156° 43′ is the apparent north angle of the calculus. Its complement is 23° 17′.

15) For *cd;*
Sine 41° 9′ 981824.
Sine 23° 17′ 959690.

Sine 15° 5′ 941514.

16) For *ad*
Sine of compl. 23° 17′, and Rad. 1996311.
Tang. compl. 41° 9′ 10,05854.

Tangent 38° 45′ 990457.

17) For *bc; bd=ba+ad,* or 38° 45′+26° 53′=65° 38′, hence
Sine of comp. 15° 5′ 998477.
Sine of comp. 65° 38′ 961550.

Sine of comp. 66° 32′ 960027.

18) For the angle *bca* there will be this proportion; 66° 32′, the side found, is to 23° 17′, the complement of the apparent angle: as 26° 53′, the apparent side, to the angle required. By sines:
Sine 26° 53′ 965530.
Sine 23° 17′ 959690.

1925220.
Sine 66° 32′ 996250.

Sine 11° 14′ 928970.

Thus we have the side *bc*=66° 32′, and the angle *bca*=11° 14′.

We must now find the side and angle at the south pole.

19) For the complement of the side *oc;* 41° 9′−22° 30′=18° 39′.

20) By decimal calculation 43′ 18″ into 18° 39′=1° 20′.

21) Here there is no need of any increase.

22) Subtract 1° 20′ from the true south angle, thus, 178° 45′ − 1° 20′ = 177° 25′; and there is therefore 177° 25′ the apparent south angle of the calculus: its complement is 2° 35′.

23) For *nc;*

Sine 41° 9′ 981824.
Sine 2° 35′ 865391.

Sine 1° 42′ 847215.

24) For *nh;*

Sine of compl. 2° 35′ and
Rad. 19,99950.
Tang. comp. 41° 9′ 10,05854.

Tangent 41° 7′ 994096.

25) For the side *gc*, first subtract; that is, 41° 7′ − 26° 53′ = 14° 14′.

Sine of compl. 1° 42′ 999981.
Sine of compl. 14° 14′ 998646.

Sine of compl. 14° 21′ 998627.

Its complement gives the side required, that is, 180° − 14° 21′ = 165° 39′.

26) For the angle *gch* there will be this proportion; as 14° 21′, or the side just found, to 2° 35′, or the complement of the apparent angle of the calculus, which is 177° 25′; so is the apparent side of the calculus, 26° 53′, to the angle required. By logarithms thus:

Sine 26° 53′ 965530.
Sine 2° 35′ 865391.

1830921.
Sine 14° 21′ 939418.

Sine 4° 37′ 890503.

Thus we have the side *gc* = 165° 39′ and the angle *gch* = 4° 37′.

Sides. Angles.
27) 66° 32′ 11° 14′
165° 39′ 4° 37′

232° 11′ : 16° 51′ :: 66° 32′ : 4° 52′

28) If 4° 52′ be subtracted from 11° 14′, there remains the declination east 6° 22′.

VII.

Calculation of the Magnetic Declination for the year 1630, *at Paris.*

North latitude 48° 51′, complement 41° 9′.

East longitude 2° 25′.

1) Between 1630 and 1720 intervene 90 years.

Hence 90° × 56′ = 84°.

2) Add these degrees together with the east longitude, to the angle 112°; that is, 112° + 84° + 2° 25′ = 198° 25′; which subtracted from 360° leaves the true north angle, 161° 35′ towards the east.

3) For *pa;*

161° 35′ − 90 = 71° 35′.
Sine 22° 30′ 958284.
Sine 71° 35′ 997716.

Sine 21° 17′ 956000.

4) For the south pole, multiply as above, thus

90° × 20′ = 30°.

5) Add these degrees together with the east longitude, to the angle 145° 30′; thus, 145° 30′+30°+2° 25′=177° 55′. And the angle 177° 55′ is the true south angle towards the west.

6) For *oh;*
177° 55′−90=87° 55′.
Sine 22° 30′ 958284.
Sine 87° 55′ 999971.

Sine 22° 29′ 958255.

7) For *pc;*
41° 9′+21° 17′=62° 26′.

8) 62° 26′×6″=6′ 15″.

9) Hence 22′ 30″+6′ 15″=28′ 45″.

10) For *po;*
180+21° 17′+22° 29′=223° 46′.

11) The square of 180°=32400 : is to the square of 223° 46′ =49600, as 28′ 45″ to 44′ 23″.

12) By decimal calculation 44′ 23″×62° 26′=4° 36′.

13) 22° 30′+4° 36′=27° 6′, and 27° 6′ is the apparent side of the calculus.

14) For this latitude there is no need of any increase. But if 4° 36′ be added to the true north angle 161° 35′, we have the apparent north angle of the calculus, 166° 11′, towards the east. The complement of which is 13° 49′.

15) For *cd;*
Sine 41° 9′ 981824.
Sine 13° 49′ 937806.

Sine 9° 3′ 919630.

16) For *ad;*
Sine compl. 13° 49′ 1998721.
Tang. compl. 41° 9′ 10,05854.

Tangent 40° 19′ 992867.

17) For *bc; bd=ba+ad,* or 27° 6′+40° 19′=67° 25′.
Sine Compl. 9° 3′ 999459.
Sine compl. 67° 25′ 958436.

Sine compl. 69° 14′ 957895.

18) For the angle *bca* is this proportion; as 67° 25′, or the side found, is to 13° 49′, the complement of the apparent angle; so is 27° 6′, or the apparent side, to the angle required:
Sine 27° 6′ 965853.
Sine 13° 49′ 937806.

1903659.
Sine 69° 14′ 997082.

Sine 6° 41′ 906557.

Thus we have the side *bc*=69° 14′, and the angle *bca*=6° 41′.

We must now find the side and angle at the south pole.

19) For the complement of the side *oc;* 41° 9′−22° 29′=18° 40′.

20) By decimal calculation 44′ 23″×18° 40′=1° 20′.

21) There is no need here of any increase or decrease.

22) Add 1° 20′ to the true south angle; thus, 177° 55′+1° 20′= 179° 15′ and thus 179° 15′ is the apparent south angle of the calculus; of which the complement is 0° 45′.

23) For *nc;*
Sine 41° 9′ 981824.
Sine 0° 45′ 811692.

Sine 0° 29′ 793516.

24) For *nh;*
Sine compl. 0° 29′ 1999998.
Tang. compl. 41° 9′ 10,05854.

Tangent 41° 9′ 994164.

25) For the side *gc*, first subtract thus; 41° 9′−27° 6′=14° 3′.

Sine of compl. 0° 29′ 999998.
Sine of compl. 14° 3′ 998681.

Sine of compl. 14° 3′ 998679.

Its complement gives the side in question, or 165° 57′.

26) For the angle *gch* we have the proportion; as 14° 3′, or the side found, to 0° 45′, or the complement of the apparent south angle, so is 27° 6′, or the apparent side, to the angle. By sines:

Sine 27° 6′ 965853.
Sine 0° 45′ 811692.

1777545.
Sine 14° 3′ 938519.

Sine 1° 24′ 839026.

Thus we have the side *gc*=165° 57′, and the angle *gch*=1° 24′.

27) Here subtract the angles, for the north magnetic pole is to the east, and the south magnetic pole to the west; thus,

69° 14′ 6° 41′
165° 57′ 1° 24′

235° 11′ : 5° 17′ :: 69° 14′ : 1° 28′

28) If 1° 28′ be subtracted from 6° 41′, there remains the east declination 5° 19′.

VIII.

Calculation of the Magnetic Declination for the year 1640, *at Paris.*

Latitude of the place 48° 51′; its complement 41° 9′.

East longitude 2° 25′.

1) 1720−1640=80; so that 10 years intervene, hence 80°×56′=74° 40′.

2) Add these degrees, together with the east longitude, to the north angle 112° thus; 112°+74° 40′+2° 25′=189° 5′, which subtracted from 360° leaves the true north angle 170° 55′ towards the east.

3) For *pa;*
170° 55′−90=80° 55′; hence

Sine 22° 30′ 958284.
Sine 80° 55′ 999452.

Sine 22° 12′ 957736.

4) For the south pole multiply as above; 80°×20′=26° 40′.

5) Add these degrees, together with the east longitude, to the south angle; 145° 30′+26° 40′+2° 25′=174° 35′, which is the true south angle towards the west.

6) For *oh;* 174° 35′−90=84° 35′.

Sine 22° 30′ 958284.
Sine 84° 35′ 999805.

Sine 22° 23′ 958089.

7) For pc;
41° 9′+22° 12′=63° 21′.

8) 63° 21′×6″=6′ 20″.

9) Hence 22′ 30″+6′ 20″=28′ 50″.

10) For po;
180°0′+22°12′+22°23′=224°35′

11) The square of 180°=32400 : the square of 224° 35′=49900 :: : 28′ 50″ : 44′ 40″.

12) By decimal calculation, 44′ 40″×63′ 21″=4° 41′.

13) 22° 30′+4° 41′=27° 11′; and thus 27° 11′ is the apparent side of the calculus.

14) Here there is no need of any increase or decrease; but if 4° 41′ be simply added to the true north angle, 170° 55′; or, 4° 41′+170° 55′, we have the apparent north angle of the calculus=175° 36′, towards the east; of which the complement is 4° 24′.

15) For cd;
Sine 41° 9′ 981824.
Sine 4° 24′ 888490.

Sine 2° 58′ 870314.

16) For ad;
Sine of compl. 4° 24′ 1999872.
Tang. compl. 41° 9′ 1005854.

Tangent 41° 4′ 994018.

17) For bc we have $bd=ba+ad$, or 41° 4′+27° 11′=68° 15′; or by logarithms:
Sine of compl. 2° 58′ 999942.
Sine of compl. 68° 15′ 956885.

Sine of compl. 68° 17′ 956827.

18) For the angle bca we have the proportion; as 68° 17′, or the side found, to 4° 24′, the complement of the apparent north angle, so is 27° 11′, the apparent side of the calculus, to the angle required.
Sine 27° 11′ 965976.
Sine 4° 24′ 888490.

1854466.
Sine 68° 17′ 996802.

Sine 2° 7′ 857664.

Thus we have the side bc=68° 17′, and the angle bca=2° 7′.

We must now find the side and angle at the south pole.

19) For the complement of the side oc; 41° 9′−22° 23′=18° 46′.

20) By decimal calculation, 44′ 40″×18° 46′=1° 26′.

21) At this latitude there is no need of increase.

22) Add 1° 26′ to the true south angle: 174° 35′+1° 26′=176° 1′; and thus 176° 1′ is the apparent south angle of the calculus to the west; of which the complement is 3° 59′.

23) For nc;
Sine 41° 9′ 981824.
Sine 3° 59′ 884177.

1866001.
Radius 10,00000.

Sine 2° 37′ 866001.

24) For nh;
Sine compl. 3° 59′, with Rad. 1999895.
Tang. compl. 41° 9′ 10,05854.

Tangent 41° 5′ 994041.

25) For the side *gc;* 41° 5′—27° 11′=13° 54′.

Sine compl. 2° 37′ 999954.
Sine compl. 13° 54′ 998709.

Sine compl. 14° 9′ 998663.

Its complement to 180° gives the side required *gc*=165° 51′.

26) For the angle *gch* we have the proportion; as 14° 9′, or the side found, to 3° 59′, the complement of the apparent south angle, so is 27° 11′, or the apparent side of the calculus, to the angle required. By logarithms:

Sine 27° 11′ 965976.
Sine 3° 59′ 884177.

1850153.
Sine 14° 9′ 938821.

Sine 7° 28′ 911332.

Thus we have the side *go*=165° 51′, and the angle *gch*=7° 28′.

27) Since one angle is to the east, the other to the west, they are not to be added, but subtracted, in order that in the operation the difference may be used.

Sides.	Angles.
68° 17′	2° 7′—difference.
165° 51′	7° 28′

234° 8′ : 5° 21′::68° 17′ : 1° 29′

28) If 1° 29′ be added to 2° 7′, we have the declination east 3° 36′.

IX.

Calculation of the Magnetic Declination for the year 1650, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

East longitude 2° 25′.

1) 1720—1650=70, so that 70 years intervene; hence 70°×56′=65° 20′.

2) Add these degrees together with the longitude 2° 25′, to the angle 112°, thus; 112° 0′+65° 20′+2° 25′=179° 45′; and 179° 45′ is thus the true north angle towards the west.

3) For *pa;*
First 179° 45′—90=89° 45′.

Sine 22° 30′ 958284.
Sine 89° 45′ 999999.

Sine 22° 30′ 958283.

4) For the south pole, multiply as above: 70°×20′=23° 20′= the number of years which intervene.

5) Add these degrees together with the east longitude, that is, 145° 30′+2° 25′+23° 20′=171° 15′, and 171° 15′ is the true south angle towards the west.

6) For *oh;*

$171^\circ\ 15'-90=81^\circ\ 15'$.

Sine 22° 30′ 958284.
Sine 81° 15′ 999491.

Sine 22° 13′ 957775.

7) For *pc;*
$41^\circ\ 9'+22^\circ\ 30'=63^\circ\ 39'$.

8) $63^\circ\ 39'\times 6''=6'\ 21''$.

9) Hence, $22'\ 30''+6'\ 21''=28'\ 51''$.

10) For *po;*
$180^\circ+22^\circ\ 30'+22^\circ\ 13'=224^\circ\ 43'$.

11) The square of $180=32400$: the square of $224^\circ\ 43'=50500$ :: $28'\ 51''$: $45'\ 13''$.

12) By decimal calculation, $45'\ 13''\times 63^\circ\ 39'=4^\circ\ 47'$.

13) $22^\circ\ 30'+4^\circ\ 47'=27^\circ\ 17'$ =the apparent side of the calculus.

14) At this latitude there is no need of increase or decrease; but subtract 4° 47′ from the true north angle: $179^\circ\ 45'-4^\circ\ 47'=174^\circ\ 58'$, and 174° 58′ is the apparent north angle of the calculus, lying towards the west, of which the complement is 5° 2′.

15) For *cd;*
Sine 41° 9′ 981824.
Sine 5° 2′ 894317.

Sine 3° 18′ 876141.

16) For *ad;*
Sine of compl. 5° 2′, and
Rad. 1999832.
Tang. compl. 41° 9′ 10,05854.

Tangent 41° 2′ 993978.

17) For *bc*, we have first $ba+ad=bd$, or $27^\circ\ 17'+41^\circ\ 2'=68^\circ\ 19'$; then by logarithms:

Sine of compl. 3° 18′ 999928.
Sine of compl. 68° 19′ 956758.

Sine of compl. 68° 22′ 956686.

18) For the angle *bca* we have the proportion, as 68° 22′, or the side just found, to 5° 2′, or the complement of the apparent north angle; so is 27° 17′, or the apparent side of the calculus, to the angle required.

Sine 27° 17′ 966123.
Sine 5° 2′ 894317.

1860440.
Sine 68° 22′ 996827.

Sine 2° 29′ 863613.

Thus we have the side $bc=68^\circ\ 22'$; and the angle $bca=2^\circ\ 29'$.

We must now find the side and angle about the south pole.

19) For the complement of the side *oc*, $41^\circ\ 9'-22^\circ\ 13'=18^\circ\ 56'$.

20) By decimal calculation, $45'\ 13''\times 18^\circ\ 56'=1^\circ\ 26'$.

21) Here there is no need of any increase or decrease.

22) Add 1° 26′ to the true south angle thus; $171^\circ\ 15'+1^\circ\ 26'=172^\circ\ 41'$; and thus 172° 41′ is the apparent south angle of the calculus, towards the west; whose complement is 7° 19′.

23) For *nc;*
Sine 41° 9′ 981824.
Sine 7° 19′ 910501.

Sine 4° 48′ 892325.

24) For *nh;*
Sine of compl. 7° 19′, with
Rad. 1999645.
Tang. compl. 41° 9′ 1005854.

Tangent 40° 55′ 993791.

25) For the side *gc* subtract thus; $40^\circ\ 55'-27^\circ\ 17'=13^\circ\ 38'$.

Sine of compl. 4° 48′ 999847.
Sine of compl. 13° 38′ 998758.

Sine of compl. 14° 27′ 998605.

Its complement gives the side *cg;* 165° 33′.

26) For the angle *gch* we have the proportion, as 14° 27′, or the side now found, to 7° 19′, or the complement of the apparent south angle, so is 27° 17′, or the apparent side of the calculus, to the angle required. By sines:

Sine 27° 17′ 966123.
Sine 7° 19′ 910501.

1876624.
Sine 14° 27′ 939713.

Sine 13° 32′ 936911.

Thus we have the side $gc=165^\circ\ 33'$; and the angle $gch=13^\circ\ 32'$.

	Sides.	Angles.
27)	68° 22′	2° 29′
	165° 33′	13° 32′

$233^\circ\ 55' : 16^\circ\ 1' :: 68^\circ\ 22' : 4^\circ\ 40'$.

28) If 2° 29′ be subtracted from 4° 40′, there remains the declination east 2° 21′.

X.

Calculation of the Magnetic Declination for the year 1665, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

East longitude from London 2° 25′.

1) $1720-1665=55$: so that 55 years intervene; hence $55^\circ\times 56'=51^\circ\ 20'$.

2) Add these degrees, together with the distance of the east longitude, to the north angle thus; $112^\circ+51^\circ\ 20'+2^\circ\ 25'=165^\circ\ 45'$; which is the true north angle to the west.

3) For *pa;*
$165^\circ\ 45'-90^\circ=75^\circ\ 45'$.

Sine 22° 30′ 958284.
Sine 75° 45′ 998642.

Sine 21° 46′ 956926.

4) For the south pole, multiply as above thus:
$55^\circ\times 20'=18^\circ\ 20'$.

5) Add these degrees, together with the longitude, to the south angle, $145^\circ\ 30'+18^\circ\ 20'+2^\circ\ 25'=166^\circ\ 15'$, which is the true south angle, to the west.

6) For *oh;*
$166^\circ\ 15'-90^\circ=76^\circ\ 15'$.

Sine 22° 30′ 958284.
Sine 76° 15′ 998737.

Sine 21° 49′ 957021.

7) For *pc*, $41^\circ\ 9'+21^\circ\ 46'=62^\circ\ 55'$.

8) $62^\circ\ 55'\times 6''=6'\ 18''$.

9) Hence $22'\ 30''+6'\ 18''=28'\ 48''$.

10) For po;
180°+21° 46′+21° 49′=223° 35′.

11) The square of 180°=32400 : the square of 223° 35′=49929 :: 28′ 48″ : 44′ 20″.

12) By decimal calculation, 44′ 20″ × 62° 55′=4° 39′.

13) 22° 30′+4° 39′=27° 9′, which is the apparent side of the calculus.

14) Here there is no need of increase, but subtract thus ; 165° 45′ −4° 39′=161° 6′, which is the apparent north angle of the calculus, of which the complement to the semicircle is 18° 54′, towards the west.

15) For cd;

Sine 41° 9′ 981824.
Sine 18° 54′ 951043.

Sine 12° 18′ 932867.

16) For ad;

Sine of compl. 18° 54′, and
Rad. 1997593.
Tang. compl. 41° 9′ 10,05854.

Tangent 39° 35′ 991739.

17) For bc add thus; $bd=ba+ad$, or 39° 35′+27° 9′=66° 44′; hence,

Sine of compl. 12° 18′ 998991.
Sine of compl. 66° 44′ 959661.

Sine of compl. 67° 18′ 958652.

18) For the angle bca we have the proportion; as 67° 18′, or the side just found, to 18° 54′, or the complement of the apparent north angle; so is 27° 9′, or the apparent side, to the required angle, bca.

Sine 27° 9′ 965927.
Sine 18° 54′ 951043.

1916970.
Sine 67° 18′ 996498.

Sine 9° 13′ 920472.

Thus we have the side bc=67° 18′ ; and the angle bca=9° 13′.

We must now find the angle and side at the south pole.

19) For the complement of the side oc; 41° 9′−21° 49′=19° 20′.

20) By decimal calculation, 44′ 20″ into 19° 20′=1° 23′.

21) There is no need here of any increase.

22) Add 1° 23′ to the south angle of the calculus thus; 166° 15′+1° 23′=167° 38′, which is the apparent south angle of the calculus, lying towards the west; its complement is 12° 22′.

23) For nc;

Sine 41° 9′ 981824.
Sine 12° 22′ 933075.

Sine 8° 6′ 914899.

24) For nh;

Sine of compl. 12° 22′ 1998980.
Tang. compl. 41° 9′ 1005854.

Tangent 40° 29′ 993126.

25) For the side gc first subtract thus; 40° 29′−27° 9′=13° 20′.

Sine of compl. 8° 6′ 999564.
Sine of compl. 13° 21′ 998810.

Sine of compl. 15° 35′ 998374.

Its complement gives the side required, or cg=164° 25′.

26) For the angle *gch* we have the proportion, as 15° 35′, or the side now found, to 12° 22′, or the complement of the apparent south angle, so is 27° 9′, or the apparent side, to the angle required.

Sine 27° 9′ 965927.
Sine 12° 22′ 933075.

1899002.
Sine 15° 35′ 942962.

Sine 21° 20′ 956040.

Thus we have the side *gc*=164° 25′; and the angle *gch*=21° 20′.

27) 67° 18′ 9° 13′
164° 25′ 21° 30′

232° 43′ : 30° 33′ :: 67° 18′ : 8° 53′.

28) If 8° 53′ be subtracted from 9° 13′, there remains the declination west 0° 20′. According to this calculation, there would be in the year 1664 no declination at Paris, but not so in the year 1666: so that between 1664 and 1670, there would be a difference of 1° 30′; but not between 1666 and 1670 as appears from observations; according to which the progression must have been 1° 30′ within three or four years, and must have made a considerable leap every year, namely, 38′, which appears too much. If there had been no declination in the year 1664, there would then be an annual progression of about 20′ or 23′; as seems also a possible conclusion from the experiments which precede, and from those which follow.

XI.

Calculation of the Magnetic Declination for the year 1670, *at Paris.*

North latitude 48° 51′; complement 41° 9′.

East longitude from London, 2° 25′.

1) 1720−1670=50; that is, 50 years intervene: hence 50° × 56′=46° 4′.

2) Add these degrees, together with the east longitude, to the north angle at London; thus 112° +2° 25′+46° 4′=160° 29′, towards the west.

3) For *pa;*

160° 29′−90°=70° 29′.
Sine 22° 30′ 958284.
Sine 70° 29′ 997430.

Sine 21° 8′ 955714.

4) For the south pole multiply as above thus; 50° × 20′=16° 40′.

5) Add these degrees, together with the east longitude, to the south angle at London thus; 145° 30′+2° 25′+16° 40′=164° 35′, towards the west.

6) For *oh;*

164° 35′−90°=74° 35′.
Sine 22° 30′ 958284.
Sine 74° 35′ 998408.

Sine 21° 39′ 956692.

7) For *pc;*
41° 9′+21° 8′=62° 17′.

8) 62° 17′×6″=6′ 14″.

9) Hence 22′ 30″+6′ 14″=28′ 54″.

10) For *po;*
180°+21° 8′+21° 39′=222° 47′.

11) The square of 180=32400 : the square of 222° 47′=49600 :: 28′ 54″ : 44′ 20″.

12) By decimal calculation, 44′ 20″×62° 17′=4° 35′.

13) 22° 30′+4° 35′=27° 5′; whence 27° 5′ is the apparent north side of the calculus.

14) At this latitude there is no need of any increase or decrease, but subtract 4° 35′ from the true north angle; viz., 160° 29′−4° 35′=155° 54′, which is the apparent north angle of the calculus towards the west; of which the complement is 24° 6′.

15) For *cd;*
Sine 41° 9′ 981824.
Sine 24° 6′ 961101.

Sine 15° 35′ 942925.

16) For *ad;*
Sine of compl. 24° 6′, and Rad. 1996039.
Tang. compl. 41° 9′ 1005854.

Tangent 38° 35′ 990185.

17) For *bc* we have first *bd* =*ba*+*ad,* or 38° 35′+27° 5′= 65° 40′.
Sine of compl. 15° 35′ 998373.
Sine of compl. 65° 40′ 961494.

Sine of compl. 66° 37′ 959867.

18) For the angle *bca* we have the proportion; as 66° 37′, the side now found, to 24° 6′, the complement of the apparent north angle; so is 27° 5′, the apparent side, to the angle required.
Sine 27° 5′ 965828.
Sine 24° 6′ 961101.

1926929.
Sine 66° 37′ 996278.

Sine 11° 41′ 930651.

Thus we have the side *bc*=66° 37′, and the angle *bca*=11° 41′.

We must now find the side and angle at the south pole.

19) For the complement of the side *oc;* 41° 9′−21° 39′=19° 30′.

20) By decimal calculation, 44′ 20″×19° 30′=1° 28′.

21) There is no need here of any increase.

22) But merely add 1° 28′ to the true south angle thus; 164° 35′+1° 28′=166° 3′, which is the apparent south angle of the calculus towards the west, of which the complement is 13° 57′.

23) For *nc;*
Sine 41° 9′ 981824.
Sine 13° 57′ 938215.

Sine 9° 8′ 920039.

24) For *nh;*
Sine compl. 13° 57′ 1998699.
Tang. compl. 41° 9′ 1005854.

Tangent 40° 18′ 992845.

25) For the side *gc*, first subtract thus; 40° 18′−9°8′=13° 13′.

Sine compl. 9° 8′ 999445.
Sine compl. 13° 13′ 998834.

Sine compl. 16° 2′ 998279.

Its complement gives the side *cg*, that is, 163° 58′.

26) For the angle *gch* we have the proportion; as 16° 2′, or the complement of the side found, to 13° 57′, the complement of the apparent north angle; so is 27° 5′, the apparent side of the calculus, to the angle required.

Sine 27° 5′ 965828.
Sine 13° 57′ 938215.

1904043.
Sine 16° 2′ 944121.

Sine 23° 25′ 959922.

Thus we have the side *gc*=163° 58′, and the angle *gch*=23° 25′.

	Sides.	Angles.
27)	66° 37′	11° 41′
	163° 58′	23° 25′

230° 35′ : 35° 6′ :: 66° 37′ : 10° 6′.

28) If 10° 6′ be subtracted from the angle 11° 41′, there remains the declination west 1° 35′.

According to observations the declination west was 1° 30′, whence there is a difference of 0° 5′.

XII.

Calculation of the Magnetic Declination for the year 1680, *at Paris.*

North latitude 48° 51′; complement 41° 9′.

East longitude from London 2° 25′.

1) 1720−1680=40; whence 40 years intervene; therefore 40° ×56′=37° 20′.

2) Add these degrees together with the longitude, to the north angle at London thus; 112°+2° 25′+37° 20′=151° 45′.

3) For *pa*;
151° 45′−90°=61° 45′.
Sine 22° 30′ 958284.
Sine 61° 45′ 994492.

Sine 19° 42′ 952776.

4) For the south pole multiply as above thus; 40° × 20′=13° 20′.

5) Add these degrees together with the longitude, to the south angle at London thus; 145° 30′ +2° 25′+13° 20′=161° 15′, which is the true south angle to the west.

6) For *oh*;
161° 15′−90°=71° 15′.
Sine 22° 30′ 958284.
Sine 71° 15′ 997631.

Sine 21° 15′ 955915.

7) For *pc*;
41° 9′+19° 42′=60° 51′.

8) $60^\circ\ 51'\times 6''=6'\ 6''$.

9) Hence $22'\ 30''+6'\ 6''=28'\ 36''$.

10) For *po*;
$180^\circ+19^\circ\ 42'+21^\circ\ 15'=220^\circ\ 57'$.

11) The square of $180=32400$: the square of $220^\circ\ 57'=48641 :: 28'\ 36'' : 42'\ 52''$.

12) By decimal calculation, $42'\ 52''\times 60^\circ\ 51'=4^\circ\ 21'$.

13) $22^\circ\ 30'+4^\circ\ 21'=26^\circ\ 51'$, which is the apparent side of the calculus.

14) There is no need of any increase; but subtract 4° 21′ from the true north angle thus; $151^\circ\ 45'-4^\circ\ 21'=147^\circ\ 24'$, which is the apparent north angle of the calculus to the west; whose complement is 32° 36′.

15) For *cd;*

Sine 41° 9′ 981824.
Sine 32° 36′ 973140.

Sine 20° 46′ 954964.

16) For *ad;*

Sine of compl. 32° 26′ 1992554.
Tang. compl. 41° 9′ 1005854.

Tangent 36° 22′ 986700.

17) For *bc* add thus; $ba+ad=bd$, or $36^\circ\ 22'+26^\circ\ 51'=63^\circ\ 13'$.

Sine of compl. 20° 46′ 997082.
Sine of compl. 63° 13′ 965380.

Sine of compl. 65° 5′ 962462.

18) For the angle *bca* we have the proportion; as 65° 5′, the side now found, to 32° 36′, the complement of the apparent north angle; so is 26° 51′, the apparent side, to the angle required.

Sine 26° 51′ 965480.
Sine 32° 36′ 973140.

1938620.
Sine 65° 5′ 995756.

Sine 15° 34′ 942864.

Thus we have the side $bc=65^\circ\ 5'$, and the angle $bca=15^\circ\ 41'$.

We must now find the side and angle at the south pole.

19) For the complement of the side *oc;* $41^\circ\ 9'-21^\circ\ 15'=19^\circ\ 54'$.

20) By decimal calculation, $19^\circ\ 54'\times 42'\ 52''=1^\circ\ 25'$.

21, 22) Here there is no need of any increase; but add 1° 25′ to the true south angle thus; $161^\circ\ 15'+1^\circ\ 25'=162^\circ\ 40'$, which is the apparent south angle of the calculus to the west; of which the complement is 17° 20′.

23) For *nc ;*

Sine 41° 9′ 981824.
Sine 17° 20′ 947411.

Sine 11° 18′ 929235.

24) For *nh ;*

Sine of compl. 17° 20′ 1997981.
Tang. compl. 41° 9′ 1005854.

Tangent 39° 50′ 992127.

25) For the side *gc;* $39^\circ\ 50'-26^\circ\ 51'=12^\circ\ 59'$.

Sine of compl. 11° 18′ 999149.
Sine of compl. 12° 59′ 998889.

Sine of compl. 17° 6′ 998038.

Its complement to 180° gives the side $gc=162^\circ\ 54'$.

26) For the angle gch we have the proportion; as 17° 6′, or the complement of the side now found, to 17° 20′, or the complement of the apparent south angle, so is 26° 57′, or the apparent side, to the angle required.

Sine 26° 51′ 965480.
Sine 17° 20′ 947411.

1912891.
Sine 17° 6 946840.

Sine 27° 14′ 966051.

Thus we have the side $gc = 162°\ 54'$; and the angle $gch = 27°\ 14'$.

27) 64° 10′ 15° 34′
162° 54′ 27° 14′

227° 4′ : 42° 4′ :: 64° 10′ : 12° 5′.

28) If 12° 5′ be subtracted from 15° 34′, there remains the declination west 3° 29′.

Experiments shew, that in the year 1680 the declination west was 2° 40′; so that the difference would be 0° 49′; but they do not make the difference greater beween the years 1670 and 1680, than 1° 10′; likewise also between the years 1680 and 1683 they make a difference of 1° 10′, which does not seem to be in agreement with the progression of the declination, inasmuch as it is thus the same within 10 years, as within three years; so that my calculation seems to have taken a mean, and to have fixed the declination at 3° 39′.

XIII.

Calculation of the Magnetic Declination for the year 1690, *at Paris.*

North latitude 48° 51′, complement 41° 9′.

East longitude 2° 25′.

1) 30 years intervene between 1690 and 1720; hence 30 × 56′ = 28°.

2) Add these degrees, together with the east longitude from London: 112° + 2° 25′ + 28° = 142° 25′, which is the true nort angle.

3) For pa;
142° 25′ − 90° = 52° 25′.

Sine 22° 30′ 958284.
Sine 52° 25′ 989898.

Sine 17° 39′ 948172.

4) For the south pole, multiply as above, 30° × 30′ = 10°.

5) Add these degrees, with the longitude, to the south angle thus; 145° 30′ + 2° 25′ + 10° = 157° 55′, and this is the true south angle, to the west.

6) For oh;
157° 55′ − 90° = 67° 55′.

Sine 22° 30′ 958284.
Sine 67° 55′ 996691.

Sine 20° 46′ 954975.

7) For pc;
41° 9′ + 17° 39′ = 58° 48′.

8) 58° 48′ × 6″ = 5° 52′.

9) Hence 22′ 30″ + 5′ 32″ = 28′ 22″.

10) For *po;*
180° + 17° 39′ + 20° 46′ = 218° 25′.

11) The square of 180° = 32400 : the square of 218° 25′ = 47600 :: 28′ 22″ : 41′ 40″.

12) By decimal calculation, 41′ 40″ × 58° 48′ = 4° 5′

13) 22° 30′ + 4° 5′ = 26° 35′, which is the apparent side of the calculus.

14) Here there is no need of increase, but subtract 4° 5′ from the true north angle thus; 142° 25′ − 4° 5′ = 138° 20′, which is the apparent north angle of the calculus to the west; of which the complement is 41° 50′.

15) For *cd;*

Sine 41° 9′ 981824.
Sine 41° 40′ 982268.

Sine 25° 56′ 964092.

16) For *ad;*

Sine of compl. 41° 40′ 1987333.
Tang compl. 41° 9′ 1005854.

Tangent 33° 8′ 981479.

17) For *bc* first add; *ba* + *ad* = *bc;* or 33° 8′ + 26° 35′ = 59° 43′.

Sine of compl. 25° 56′ 995390.
Sine of compl. 59° 43′ 970267.

Sine of compl. 63° 2′ 965657.

18) For the angle *bca* we have the proportion; as 63° 2′, the side now found, to 41° 40′, the complement of the apparent north angle, so is 26° 35′, the apparent side, to the angle required.

Sine 26° 35′ 965079.
Sine 41° 40′ 982268.

1947347.
Sine 63° 2′ 995001.

Sine 19° 30′ 952346.

Thus we have the side *bc* = 63° 2′, and the angle *bca* = 19° 30′. We must now find the side and angle at the south pole.

19) For the complement of the side *oc;* 41° 9′ − 20° 46′ = 20° 23′.

20) By decimal calculation, 20° 23′ × 41′ 40″ = 1° 23′.

21) At this latitude there is no need of increase.

22) Add therefore 1° 23′ to the true south angle; or 157° 35′ + 1° 23′ = 158° 58′, which is the apparent south angle of the calculus, lying to the west; of which the complement is 21° 2′.

23) For *nc;*

Sine 41° 9′ 981824.
Sine 21° 2′ 955498.

Sine 13° 40′ 937322.

24) For *nh;*

Sine of compl. 21° 2′ 1997005.
Tang. compl. 41° 9′ 1005854.

Tangent 39° 12′ 991151.

25) For the side *gc* first subtract; or 39° 12′ − 26° 35′ = 12° 37′; hence

Sine of compl. 13° 40′ 998752.
Sine of compl. 12° 37′ 998938.

Sine of compl. 18° 31′ 997690.

Its complement to 180° gives the side required *cg* = 161° 29′.

26) For the angle *gch* we have the proportion; as 18° 31′, or the side now found, to 21° 2′, the complement of the apparent south angle; so is 26° 35′, or the apparent side, to the angle required.

Sine 26° 35′ 965079.
Sine 21° 2′ 955466.
1920545.
Sine 18° 31′ 950185.
Sine 30° 21′ 970360.

Thus we have the side $gc = 161°$ 29′ and the angle $gch = 30°$ 21′.

27) 63° 2′ 19° 30′
161° 29′ 30° 21′
224° 31′ : 49° 51′ :: 63° 2′ : 14° 0′

28) Subtract 14° 0′ from the north angle, 19° 30′, and there remains the declination west 5° 30′, for the year 1690.

XIV.

Calculation of the Magnetic Declination for the year 1700, *at Paris.*

North latitude 48° 51′; complement 41° 9′.

Longitude east from London 2° 25′.

1) 1720 − 1700 = 20: thus 20 years intervene; hence 20 × 56′ = 18° 40′.

2) Add these degrees together with the east longitude thus; 112° + 2° 25′ + 18° 40′ = 133° 5′, which is the true north angle.

3) For *pa*;
133° 5′ − 90° = 43° 5′.

Sine 22° 30′ 958284.
Sine 43° 5′ 983446.
Sine 15° 9′ 941730.

4) For the south pole multiply as above; or 20° × 20′ = 6° 40′.

5) Add these degrees, together with the longitude, to the south angle at London; or 145° 30′ + 2° 25′ + 6° 40′ = 154° 35′, which is the true south angle.

6) For *oh*;
154° 35′ − 90° = 64° 35′.

Sine 22° 30′ 958284.
Sine 64° 35′ 995579.
Sine 20° 13′ 953863.

7) For *pc*;
41° 9′ + 15° 9′ = 56° 18′.

8) 56° 18′ × 6″ = 5′ 38″.

9) Hence 22′ 30″ + 5′ 38″ = 28′ 8″.

10) For *po*;
180° + 15° 9′ + 20° 13′ = 215° 22′.

11) The square of 180 = 32400: the square of 215° 22′ = 46400 :: 28′ 8″ : 40′ 6″.

12) By decimal calculation; 40′ 6″ × 56° 18′ = 3° 44′.

13) 22° 30′ + 3° 44′ = 26° 14′, which is the apparent side of the calculus.

14) There is no need here of either increase or decrease; but merely subtract 3° 44′ from the true north angle; or 133° 5′ − 3° 44′ = 129° 21′, which is the apparent north angle of the calculus, at the west;

of which the complement is 50° 39′.

15) For cd;

Sine 41° 9′ 981824.
Sine 50° 39′ 988834.

Sine 30° 35′ 970658.

16) For ad;

Sine of compl. 50° 39′ 1980212.
Tang compl. 41° 9′ 1005854.

Tangent 28° 59′ 974358.

17) For bc add thus; $ba+ad=bd$; or 28° 59′+26° 14′=55° 13′.

Sine of compl. 30° 35′ 993494.
Sine of compl. 55° 13′ 975623.

Sine of compl. 60° 35′ 969117.

18) For the angle bca we have the proportion; as 60° 35′, or the side found, to 50° 39′, or the complement of the apparent angle, so is 26° 14′, or the apparent side of the calculus, to the angle required.

Sine 26° 14′ 964545.
Sine 24° 1′ 988834.

1953379.
Sine 19° 43′ 994005.

Sine 23° 6′ 959374.

And thus we have the side bc= 60° 35′, and the angle bca=23° 6′.

We must now find the side and angle at the south pole.

19) For the complement of the side oc; 41° 9′−20° 13′=20° 56′.

20) By decimal calculation, 20° 56′×40′ 6″=1° 24′.

21) There is no need here of any reduction.

22) But add 1° 24′ to the true south angle; or 154° 35′+1° 24′ =155° 59′, which is the apparent south angle of the calculus lying towards the west; the complement of which is 24° 1′.

23) For nc;

Sine 41° 9′ 981824.
Sine 24° 1′ 960959.

Sine 15° 32′ 942783.

24) For nh;

Sine of compl. 24° 1′ 1996067.
Tang. compl. 41° 9′ 1005854.

Tangent 38° 23′ 990113.

25) For the side gc first subtract thus: 38° 32′−26° 14′= 12° 18.′

Sine of compl. 15° 33′ 998380.
Sine of compl. 12° 18′ 998991.

Sine of compl. 19° 43′ 997371.

Its complement gives the side cg=160° 17′.

26) For the angle gch we have the proportion; as 19° 43′, the side now found, to 24° 1′, the complement of the apparent south angle, so is 26° 14′, or the apparent side of the calculus, to the angle required.

Sine 26° 14′ 964545.
Sine 24° 1′ 960959.

1925504.
Sine 19° 43′ 952810.

Sine 32° 13′ 972694.

Thus we have the side go=160° 17′; likewise the angle gch=32° 13′.

	Sides.	Angles.
27)	60° 35′	23° 6′.
	160° 17′	32° 13′.

220° 52′ : 55° 19′ :: 60°35′ : 15° 6′.

28) If 15° 6′ be subtracted from 23° 6′, there remains the declination west 8° 0′. According to observations the declination west seems to have been 8° 12′; whence there is a difference of 0° 12′.

XV.

Calculation of the Magnetic Declination for the year 1710, *at Paris.*

North latitude 48° 51′; complement 41° 9′.

Longitude east from London 2° 25′.

1) 1720−1710=10; thus ten years intervene; hence 10 × 56′ =9° 20′.

2) Add these degrees, together with the east longitude, to the north angle at London; thus 112° + 2° 25′+9° 20′=123° 45′, which is the true north angle.

3) For *pa;*
123° 45′−90°=33° 45′.
Sine 22° 30′ 958284.
Sine 33° 45′ 974474.

Sine 12° 16′ 932758.

4) For the south pole multiply as above thus; 10 × 20′=3′ 20″.

5) Add these degrees to the south angle at London; or 145° 30′+2° 25′+3° 20′=151° 15′.

6) For *oh;*
151° 15′−90°=61° 15′.
Sine 22° 30′ 958284.
Sine 61° 15′ 994286.

Sine 19° 36′ 952570.

7) For *pc;*
41° 9′+12° 16′=53° 25′.

8) 53° 25′ × 6″=5′ 20″.

9) Hence 22′ 30″+5′ 20″=27′ 50″.

10) For *po;*
180°+12° 16′+19° 36′=211°52′.

11) The square of 180°=32400: the square of 211° 52′=44900 :: 27′ 50″ : 38′ 45″.

12) By decimal calculation; 38′ 45″ × 53° 25′=3° 25′.

13) 22° 30′+3° 25′=25° 55′, which is the apparent side of the calculus.

14) There is no need here of any reduction, but merely subtract 3° 25′ from the true north angle thus; 123° 45′−3° 25′=120° 20′, which is the apparent north angle of the calculus, lying to the west, of which the complement is 59° 40′.

15) For *cd;*
Sine 41° 9′ 981824.
Sine 59° 40′ 993606.

Sine 34° 37′ 975430.

16) For *ad;*

Sine of compl. 59° 40′ 1970331.
Tang. compl. 41° 9′ 1005854.

Tangent 23° 48′ 964457.

17) For bc first add thus: $ba+ad=bc$, or 23° 48′+25° 55′=49° 43′.

Sine of compl. 34° 37′ 991538.
Sine of compl. 49° 43′ 981061.

Sine of compl. 57° 52′ 972599.

18) For the angle bca we have the proportion; as 57° 52′, or the side now found, to 59° 40′, or the complement of the apparent north angle, so is 25° 55′, or the apparent side, to the angle required.

Sine 25° 55′ 964054.
Sine 59° 40′ 993606.

1957660.
Sine 57° 52′ 992778.

Sine 26° 28′ 964882.

Thus we have the side bc=57° 52′, and the angle bca=26° 28′.

We must now find the side and angle at the south pole.

19) For the complement of the side oc; 41° 9′−19° 36′=21° 23′.

20) By decimal calculation, 21° 23′ × 38° 45′=1° 22′.

21) At this latitude there is no need of reduction.

22) But add 1° 22′ to the true south angle thus; 151°+1° 22′ =152° 37′, which is the apparent south angle of the calculus, lying to the west; of which the complement is 27° 23′.

23) For nc;

Sine 41° 9′ 981824.
Sine 27° 23′ 966270.

Sine 17° 37′ 948094.

24) For nh;

Sine of compl. 27° 23′ 1994838.
Tang compl. 41° 9′ 1005854.

Tangent 37° 52′ 989084.

25) For the side gc first subtract thus; 37° 52′−25° 55′=11° 57′.

Sine of compl. 17° 37′ 997914.
Sine of compl. 11° 57′ 999048.

Sine of compl. 21° 11′ 996962.

Its complement gives the side gc=158° 49′

26) For the angle gch we have the proportion; as 21° 11′, or the side now found, to 27° 23′, the complement of the apparent south angle, so is 25° 55′, or the apparent side of the calculus, to the angle required.

Sine 25° 55′ 964054.
Sine 27° 23′ 966270.

1930324.
Sine 21° 11′ 955793.

Sine 33° 48′ 974531.

Thus we have the side gc=158° 49′, and the angle gch=33° 48′.

27) 57° 52′ 26° 28′
158° 49′ 33° 48′

216° 51′ : 60° 16′ :: 57° 52′ : 16° 0′

28) If 16° 0′ be subtracted from the north angle, 26° 28′, there remains the declination west 10° 28′.

According to observations it seems to have been 10° 50′, which would shew a difference of 0° 22′; but 1709 is placed at 10° 15′; 1710 at 10° 50′; 1711 at 10° 50′; hence between 1709 and 1711, the mean is evidently 10° 28′; so that the annual progression would be 0° 22′.

XVI.

Calculation of the Magnetic Declination for the year 1720, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London 2° 25′.

1) Here there are no years intervening, because our calculation begins from 1720; and hence we have only to add the longitude.

2) 112°+2° 25′=114° 25′, so that the true north angle=114°25′.

3) For *pa*;
114° 25′−90°=24° 25′.
Sine 22° 30′ 958284.
Sine 24° 25′ 961633.

Sine 9° 6′ 919917.

4) The same remark applies to the south angle: no years intervene, and hence,

5) We have only to add the east longitude; 145° 30′+2° 25′ =147° 55′, which is the true south angle made with the meridian of Paris.

6) 147° 55′−90°=57° 55′.
Sine 22° 30′ 958284.
Sine 57° 55′ 992802.

Sine 18° 55′ 951086.

7) For *pc*;
41° 9′+9° 6′=50° 15′.

8) 50° 15′×6″=5′ 0″.

9) Hence 22′ 30″+5′=27′ 30″.

10) For *po*;
180°+9° 6′+18° 55′=208° 1′.

11) The square of 180°=32400: the square of 208° 1′=43264 :: 27′ 30″ : 36′ 45″.

12) By decimal calculation, 36′ 45″×50° 15′=3° 3′.

13) 22° 30′+3° 3′=25° 33′, which is the apparent side of the calculus.

14) At this latitude there is no need of reduction, but simply subtract 3° 3′ from the true north angle thus: 114° 25′−3° 3′=111° 22′, which is the apparent north angle of the calculus, lying to the west, of which the complement is 68° 38′.

15) For *cd*;
Sine 41° 9′ 981824.
Sine 68° 38′ 996907.

Sine 37° 47′ 978731.

16) For *ad*;
Sine of compl. 68° 38′ 1956150.
Tang. compl. 41° 9′ 1005854.

Tangent 17° 39′ 950296.

17) For *bc* first add thus; *ba* +*ad*=*bd*, or 17° 39′+25° 33′= 43° 12′.

Sine of compl. 37° 47′ 989781.
Sine of compl. 43° 12′ 986271.

Sine of compl. 54° 49′ 976052.

18) For the angle *bca* we have the proportion; as 54° 49′, or the side now found, to 68° 38′, the complement of the apparent north angle, so is 25° 33′ the apparent side of the calculus, to the angle required.

Sine 25° 33′ 963477.
Sine 68° 38′ 996907.

1960384.
Sine 54° 49′ 991238.

Sine 29° 26′ 969146.

Thus we have the side *bc*=54° 49′; and the angle *bca*=29° 26′.

We must now find the side and angle at the south pole.

19) For the complement of the side *oc;* 41° 9′−18° 55′=22° 14′.

20) By decimal calculation, 36′ 45″ × 22° 14′=1° 22′.

21) Here there is no need of reduction.

22) But simply add 1° 22′ to the true south angle thus; 147° 55′+1° 22′=149° 17′, which is the apparent south angle of the calculus, at the west: its complement is 30° 43′.

23) For *nc ;*

Sine 41° 9′ 981824.
Sine 30° 43′ 970824.

Sine 19° 38′ 952648.

24) For *nh ;*

Sine of compl. 30° 43′ 1993435.
Tang. compl. 41° 9′ 1005854.

Tangent 36° 55′ 987581.

25) For the side *gc* first subtract thus; 36° 55′−25° 33′= 11° 22′.

Sine of compl. 19° 38′ 997398.
Sine of compl. 11° 22′ 999139.

Sine of compl. 22° 35′ 996537.

Its complement gives the side *cg*=157° 25′.

26) For the angle *gch* we have the proportion; as 22° 35′, the side now found, to 30° 43′, the complement of the apparent south angle, so is 25° 33′, the apparent side of the calculus, to the angle required.

Sine 25° 33′ 963477.
Sine 30° 43′ 970824.

1934301.
Sine 22° 35′ 958436.

Sine 35° 0′ 975865.

Thus we have the side *gc*=157° 25′, and the angle *gch*=35° 0′.

27) 54° 49′ 29° 36′
157° 25′ 35° 0′

212° 14′ : 64° 26′ :: 54° 49′ : 16° 38′.

28) If 16° 38′ be subtracted from the north angle, 29° 36′, there remains the declination west, 12° 48′.

According to experiments, the declination in the year 1720, at Paris, seems to have been 13° 0′; making a difference of 0° 12′.

XVII.

Calculation of the Magnetic Declination for the year 1730, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London 2° 25′.

1) 1730−1720=10; therefore 10 years intervene; hence 10°×56′=9° 20′.

2) Subtract these degrees, but adding the east longitude as before; thus 112°+2° 25′−9° 20′=105° 5′; and so 105° 5′ is the true north angle.

3) For *pa;*
105° 5′−90°=15° 5′.
Sine 22° 30′ 958284.
Sine 15° 5′ 941534.

Sine 5° 43′ 899818.

4) For the south pole, multiply as above; 10°×20′=3° 20′.

5) Subtract these degrees, and add the longitude to the south angle at London thus; 145° 30′ +2° 25′−3° 20′=144° 35′, which is the true south angle.

6) For *oh;*
144° 35′−90°=54° 35′.
Sine 22° 30′ 958284.
Sine 54° 35′ 991113.

Sine 18° 10′ 949397.

7) For *pc;*
41° 9′+5° 43′=46° 52′.

8) 46° 52′×6″=4′ 42″.

9) Hence 22′ 30″+4′ 42″=27′ 12″.

10) For *po;*
180°+5° 43′+18° 10′=203° 53′.

11) The square of 180=32400: the square of 203° 53′=41616 :: 27′ 12″ : 36′ 30″.

12) By decimal calculation; 36′ 30″×46° 52′=2° 51′.

13) 22° 30′+2° 51′=25° 21′, which is the apparent side of the calculus.

14) At this latitude there is no need of reduction, but simply subtract 2° 51′ from the true north angle: 105° 5′−2° 51′=102° 14′; which is the apparent north angle of the calculus, at the west; its complement being 77° 46′.

15) For *cd;*
Sine 41° 9′ 981824.
Sine 77° 46′ 999002.

Sine 40° 1′ 980826.

16) For *ad;*
Sine of compl. 77° 46′ 1932611.
Tang compl. 41° 9′ 1005854.

Tangent 10° 29′ 926757.

17) For *bc* first add thus: *ba*+*ad*=*bd*, or 10° 29′+25° 21′=35° 50′.
Sine of compl. 40° 1′ 988414.
Sine of compl. 35° 50′ 990887.

Sine of compl. 51° 37′ 979301.

18) For the angle *bca* we have the proportion; as 51° 37′, the side now found, to 77° 46′, the

complement of the apparent north angle, so is 25° 21′, the apparent side of the calculus, to the angle required.

Sine 25° 21′ 963159.
Sine 77° 46′ 999002.

1962161.
Sine 51° 37′ 989424.

Sine 32° 15′ 972737.

Thus we have the side bc=51° 37′, and the angle bca=32° 15′.

We must now find the side and angle about the south pole.

19) For the complement of the side oc; 41° 9′−18° 10′=22° 59′.

20) By decimal calculation, 36′ 20″ × 22° 59′=1° 24′.

21) At this latitude there is no need of reduction.

22) But add 1° 24′ to the true south angle thus; 144° 35′+1° 24′=145° 59′, which is the apparent south angle of the calculus, at the west; its complement being 34° 1′.

23) For nc;

Sine 41° 9′ 981824.
Sine 34° 1′ 974775.

Sine 21° 36′ 956599.

24) For nh;

Sine of compl. 34° 1′ 1991849.
Tang compl. 41° 9′ 1005854.

Tangent 35° 55′ 985995.

25) For the side gc first subtract; 35° 55′--25° 21′=10° 34′.

Sine of compl. 21° 36′ 996837.
Sine of compl. 10° 34′ 999257.

Sine of compl. 23° 56′ 996094.

Its complement gives the side cg=156° 4′.

26) For the angle gch we have the proportion; as 23° 56′, the side now found, to 34° 1′, the complement of the apparent south angle, so is 25° 1′, or the apparent side of the calculus, to the angle required.

Sine 25° 21′ 963159.
Sine 34° 1′ 974775.

1937934.
Sine 23° 56′ 960817.

Sine 36° 11′ 977117.

Thus we have the side gc=156° 4′, and the angle gch=36° 11′.

27) 51° 37′ 32° 15′
156° 4′ 36° 11′

207° 41′ : 68° 26′ :: 51 37° : 16° 58′.

28) If 16° 58′ be subtracted from 32° 15′, there remains the declination west, 15° 17′.

I have not yet been able to learn the declination at Paris for the year 1730, but I do not think there is much difference between it and the result of my calculation. Between the year 1720 and this of 1730, the annual progression appears to have been almost 15 minutes; whence

Years.	Declination. Deg.	Declination. Min.
1720	12	48
1721	13	3
1722	13	18
1723	13	33
1724	13	48
1725	14	3
1726	14	18
1727	14	33
1728	14	48
1729	15	2
1730	15	17

XVIII.

Calculation of the Magnetic Declination for the year 1740, *at Paris.*

North latitude $48^\circ\ 51'$; its complement $41^\circ\ 9'$.

Longitude east from London $2^\circ\ 25'$.

1) $1740-1720=20$; thus 20 years intervene; hence $20^\circ \times 56' = 18^\circ\ 40'$.

2) Subtract these degrees, but add $2^\circ\ 25'$ to the given angle with the meridian of London; $112^\circ + 2^\circ\ 25' - 18^\circ\ 40' = 95^\circ\ 45'$.

3) For *pa;*
$95^\circ\ 45' - 90^\circ = 5^\circ\ 45'$.
Sine $22^\circ\ 30'$ 958284.
Sine $5^\circ\ 45'$ 891807.

Sine $1^\circ\ 48'$ 850091.

4) For the south pole multiply as above: $20^\circ \times 20' = 6^\circ\ 40'$.

5) Subtract $6^\circ\ 40'$ from the south angle at London, but add $2^\circ\ 25'$; thus $145^\circ\ 30' + 2^\circ\ 25' - 6^\circ\ 40' = 141^\circ\ 5'$; which is the true south angle at the west.

6) For *oh;*
$141^\circ\ 5' - 90^\circ = 51^\circ\ 5'$.
Sine $22^\circ\ 30'$ 958284.
Sine $51^\circ\ 5'$ 989101.

Sine $17^\circ\ 19'$ 947385.

7) For *pc;*
$41^\circ\ 9' + 1^\circ\ 48' = 42^\circ\ 57'$.

8) $42^\circ\ 57' \times 6'' = 4'\ 18''$.

9) Hence $22'\ 30'' + 4'\ 18'' = 26'\ 48''$.

10) For *po;*
$180^\circ + 1^\circ\ 48' + 17^\circ\ 19' = 194^\circ\ 7'$.

11) The square of $180^\circ = 32400$: the square of $194^\circ\ 7' = 37636 :: 26'\ 48'' : 31'\ 20''$.

12) By decimal calculation, $31'\ 20'' \times 42^\circ\ 57' = 2^\circ\ 14'$.

13) $22^\circ\ 30' + 2^\circ\ 14' = 24^\circ\ 44'$, which is the apparent side of the calculus.

14) At this latitude there is no need of reduction, but simply subtract $2^\circ\ 14'$ from the true north angle; $95^\circ\ 45' - 2^\circ\ 14' = 93^\circ\ 21'$, which is the apparent north angle of the calculus, at the west; its complement being $86^\circ\ 29'$.

15) For *cd;*
Sine $41^\circ\ 9'$ 981824.
Sine $86^\circ\ 29'$ 999918.

Sine $41^\circ\ 3'$ 981742.

16) For *ad;*
Sine compl. $86^\circ\ 29'$ 1878773.
Tang. compl. $41^\circ\ 9'$ 1005854.

Tangent $3^\circ\ 4'$ 872919.

17) For *bc*, first add; $ba + ad = bd$; or $3^\circ\ 4' + 24^\circ\ 44' = 27^\circ\ 48'$.
Sine compl. $41^\circ\ 3'$ 987745.
Sine compl. $27^\circ\ 48'$ 994673.

Sine compl. $48^\circ\ 10'$ 982418.

18) For the angle *bca* we have the proportion; as $48^\circ\ 10'$, or the side now found, to $86^\circ\ 29'$, or the complement of the apparent

north angle, so is 24 44′, or the apparent side, to the angle required.

Sine 24° 44′ 962158.
Sine 86° 29′ 999918.

1962076.
Sine 48° 10′ 987220.

Sine 34° 5′ 974856.

Thus we have the side *bc*=48°, 10′, and the angle *bca*=34° 5′.

We must now find the side and angle about the north pole.

19) For the complement of the side *oc;* 41° 9′−17° 19′=23° 50′.

20) By decimal calculation, 23° 50′×31′ 20″=1° 15′.

21, 22) Here there is no need of reduction, but simply add to the south angle at London thus: 141° 5′+1° 15′=142° 20′, which is the apparent south angle of the calculus, at the west; its complement being 37° 40′.

23) For *nc;*

Sine 41° 9′ 981824.
Sine 37° 40′ 978608.

Sine 23° 42′ 960432.

24) For *nh;*

Sine compl. 37° 40′ 1989849.
Tang. compl. 41° 9′ 1005854.

Tangent 34° 40′ 983995.

25) For the side *gc* first subtract; 34° 40′−24° 44′=9° 56′.

Sine of compl. 23° 42′ 996173.
Sine of compl. 9° 56′ 999344.

Sine of compl. 25° 52′ 995417.

If we take the complement, we have the side in question, *gc*= 154° 8′.

26) For the angle *gch* we have the proportion; as 25° 52′, or the side now found, to 37° 40′, or the complement of the apparent south angle, so is 24° 44′, or the apparent side, to the angle required.

Sine 24° 44′ 962158.
Sine 37° 40′ 978608.

1940766.
Sine 25° 52′ 963976.

Sine 35° 52′ 976790.

Thus we have the side *gc*=154° 8′, and the angle *gch*=35° 52′.

27) 48° 10′ 34° 5′
154° 8′ 35° 52′

202° 18 : 69° 57′ :: 48° 10′ : 16° 38′.

28) If 16° 38′ be subtracted from the angle, 34° 5′, there remains the declination west 17° 27′.

XIX.

Calculation of the Magnetic Declination for the year 1750, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London 2° 25′.

1) 1750−1720=30; thus 30 years intervene; hence 30°×56′ =28° 0′.

2) Subtract these degrees, and

add the longitude east from London thus: 112° 0′+2° 25′−28° 0′=86° 25′, which is the true north angle to the west.

3) For *pa;*
90°−86° 25′=3° 35′.
Sine 22° 30′ 958284.
Sine 3° 35′ 879588.

Sine 1° 22′ 837872.

4) For the south pole multiply as above; 30°×20′=10° 0′.

5) Subtract these degrees from the south angle at London thus; 145° 30′+2° 25′−10° 0′=137° 55′, which is the true south angle at the west.

6) For *oh;*
137° 55′−90°=47° 55′.
Sine 22° 30′ 958284.
Sine 47° 55′ 987050.

Sine 16° 30′ 945334.

7) For *pc;*
41° 9′−1° 22′=39° 47′.

8) 39° 47′×6″=3′ 58″.

9) 22′ 30″+3′ 58″=26′ 28″.

10) For *po;*
180°+16° 30′−1° 22′=194° 38′.

11) The square of 180=32400: the square of 194° 38′=37860 :: 26′ 38″ : 31′ 0″.

12) By decimal calculation; 31′×39° 47′=2° 3′.

13) 22° 30′+2° 3′=24° 33′, which is the apparent side of the calculus.

14) There is no need of any reduction at this latitude, but only subtract from the true angle thus: 86° 25′−2° 3′=84° 22′; which is the apparent angle of the calculus, at the north: nor is there any occasion here for the complement.

15) For *cd;*
Sine 41° 9′ 981824.
Sine 84° 22′ 999789.

Sine 40° 54′ 981613.

16) For *ad;*
Sine compl. 84° 22′ 1899194.
Tang. compl. 41° 9′ 1005854.

Tangent 4° 34′ 893340.

17) For *bc* first subtract; *ba*−*ad*=*bd*, or 24° 33′−4° 34′=19° 59′.
Sine compl. 40° 54′ 987843.
Sine compl. 19° 59′ 997303.

Sine compl. 44° 44′ 985146.

18) For the angle *bca* we have the proportion; as 44° 44′, or the side now found, to 84° 22′, or the apparent north angle; so is 24° 33′, or the apparent side of the calculus, to the angle required.
Sine 24° 33′ 961855.
Sine 84° 22′ 999789.

1961644.
Sine 44° 44′ 984745.

Sine 35° 59′ 976899.

Thus we have the side *bc*=44° 44′; and the angle *bca*=35° 59′.

We have now to find, in the same way, the side and angle at the south magnetic pole.

19) For the complement of the side *oc*; 41° 9′−16° 30′=24° 39′.

20) By decimal calculation; 31′ ×24° 39′=1° 16′.

21) There is no need here of any reduction.

22) But simply add 1° 16′ to the true south angle; 137° 55′+1° 16′=139° 11′, which is the apparent south angle of the calculus, at the west; of which the complement is 40° 49.′

23) For *nc*;

Sine 41° 9′ 981824.
Sine 40° 49′ 981534.

Sine 25° 28′ 963358.

24) For *nh*;

Sine compl. 40° 49′ 1987898.
Tang. compl. 41° 9′ 1005854.

Tangent 33° 28′ 982044.

25) For the side *gc* first subtract; 33° 28′−24° 33′=8° 55′.

Sine compl. 25° 28′ 995561.
Sine compl. 8° 55′ 999472.

Sine compl. 26° 53′ 995033.

Its complement gives the side *cg*=153° 7′.

26) For the angle *gch* we have the proportion; as 26° 53′, or the side now found, to 40° 49,′ the complement of the apparent south angle, so is 24° 33′, or the apparent side of the calculus, to the angle required.

Sine 24° 33′ 961855.
Sine 40° 49′ 981534.

1943389.
Sine 26° 53′ 965530.

Sine 36° 55′ 977859.

Thus we have the side *gc*=153° 7′, and the required angle *gch*=36° 55′.

27) 44° 44′ 35° 59′
153° 7′ 36° 55′

197° 51′ : 72° 54′ :: 44° 44′ : 16° 30′.

28) If 16° 30′ be subtracted from the north angle, 35° 59′, there remains the declination west, 19° 29′.

XX.

Calculation of the Magnetic Declination for the year 1760, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London 2° 25′.

1) 1760−1720=40; whence 40 years intervene: hence 40°×56′=37° 20′.

2) Subtract these degrees, but add the east longitude; thus 112° 0′+2° 25′−37° 20′=77° 5′, which is the true north angle.

3) For *pa*;

90°−77° 5′=12° 55′.
Sine 22° 30′ 958284.
Sine 12° 55′ 934934.

Sine 4° 34′ 893218.

4) For the south pole multiply

as above thus; $40^\circ \times 20' = 13^\circ\ 20'$.

5) Subtract these degrees, 13° 20′, and add the east longitude thus; $145^\circ\ 30' + 2^\circ\ 25' - 13^\circ\ 20' = 134^\circ\ 35'$, which is the true south angle at the west.

6) For *oh;*
$134^\circ\ 35' - 90^\circ = 44^\circ\ 35'$.
Sine 22° 30′ 958284.
Sine 44° 35′ 984630.

Sine 15° 35′ 942914.

7) For *pc;*
$41^\circ\ 9' - 4^\circ\ 34' = 36^\circ\ 35'$.

8) $36^\circ\ 35' \times 6'' = 3'\ 39''$.

9) Hence $22'\ 30'' + 3'\ 39'' = 26'\ 9''$.

10) For *po;*
$180^\circ + 15^\circ\ 35' - 4^\circ\ 34' = 191^\circ\ 1'$.

11) The square of $180^\circ = 32400$: the square of $191^\circ\ 1' :: 26'\ 9'' : 29'\ 18''$.

12) By decimal calculation, $29'\ 18'' \times 36^\circ\ 35' = 1^\circ\ 51'$.

13) $22^\circ\ 30' + 1^\circ\ 51' = 24^\circ\ 21'$, which is the apparent side of the calculus.

14) There is no need here of any reduction, but simply subtract 1° 51′ from the true north angle; $77^\circ\ 5' - 1^\circ\ 51' = 75^\circ\ 14'$, which is the apparent south angle, placed towards the west. There is no need here of the complement.

15) For *cd;*
Sine 41° 9′ 981824.
Sine 75° 14′ 998541.

Sine 39° 31′ 980365.

16) For *ad;*
Sine compl. 75° 14′ 1940634.
Tang. compl. 41° 9′ 1005854.

Tangent 12° 33′ 934780.

17) For *bc* first subtract; $ba - ad = bd$; or $12^\circ\ 33' - 24^\circ\ 21' = 11^\circ\ 48'$.

Sine compl. 39° 31′ 988730.
Sine compl. 11° 48′ 999072.

Sine compl. 40° 57′ 987802.

18) For the angle *bca* we have the proportion; as 40° 57′, or the side now found, to 75° 14′, the apparent north angle of the calculus, so is 24° 21′, or the apparent side of the calculus, to the angle required.

Sine 24° 21′ 961522.
Sine 75° 14′ 998541.

1960063.
Sine 40° 57′ 981650.

Sine 37° 28′ 978413.

Thus we have the north side $bc = 40^\circ\ 57'$, and the north angle $bca = 37^\circ\ 28'$.

We must now find in the same manner the south side and angle.

19) For the complement of the side *oc;* $41^\circ\ 9' - 15^\circ\ 35' = 25^\circ\ 34'$.

20) By decimal calculation, $29'\ 18'' \times 25^\circ\ 34' = 1^\circ\ 18'$.

21) There is no need of any reduction at this latitude.

22) But simply add 1° 18′ to the true south angle; $134^\circ\ 35' + 1^\circ\ 18' = 135^\circ\ 53'$, which is the apparent south angle of the cal-

culus at the west; its complement is 44° 7′.

23) For nc;

Sine 41° 9′ 981824.
Sine 44° 7′ 984268.

Sine 27° 16′ 966092.

24) For nh;

Sine compl. 44° 7′ 1985607.
Tang. compl. 41° 9′ 1005854.

Tangent 32° 6′ 979753.

25) For the side gc first subtract thus; 32° 6′−24° 21′=7° 45′.

Sine compl. 27° 16′ 994884.
Sine compl. 7° 45′ 999601.

Sine compl. 28° 16′ 994485.

Its complement gives the side cg=151° 44′.

26) For the angle gch we have the proportion; as 28° 16′, the side now found, to 44° 7′, the complement of the apparent south angle, so is 24° 21′, or the apparent side of the calculus, to the angle required.

Sine 24° 21′ 961522.
Sine 44° 7′ 984268.

1945790.
Sine 28° 16′ 967539.

Sine 37° 18′ 978251.

Thus we have the side gc=151° 44′, and the angle gch=37° 18′.

27) 40° 57′ 37° 28′
151° 44′ 37° 18′

192° 41′ : 74° 46′ :: 40° 57′ : 15° 54′,

28) If 15° 54′ be subtracted from the angle 37° 28′, there remains the declination west, 21° 34′.

XXI.

Calculation of the Magnetic Declination for the year 1770, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London, 2° 25′.

1) 1770−1720=50; therefore 50 years intervene; hence 50°×56′=46° 40′.

2) Subtract these degrees, and add the east longitude thus; 112° 0′ +2° 25′−46° 40′=67° 45′; and therefore 67° 45′ is the true north angle towards the west.

3) For pa;

90°−67° 45′=22° 15′.

Sine 22° 30′ 958284.
Sine 22° 15′ 957823.

Sine 8° 20′ 916107.

4) For the south pole multiply as above; 50°×20′=16° 40′.

5) Subtract these degrees, and add the east longitude thus; 145° 30′+2° 25′−16° 40′=131° 15′, which is the true south angle towards the west.

6) For oh;

131° 15′−90°=41° 15′.
Sine 22° 30′ 958284.
Sine 41° 15′ 981911.

Sine 14° 37′ 940195.

7) For *pc;*
41° 9′−8° 20′=32° 49′.

8) 32° 49′×6″=3′ 15″.

9) Hence 22′ 30″+3′ 15″=25′ 45″.

10) For *po;*
180°+14° 37′−8° 20′=186° 17′.

11) The square of 180=32400: the square of 186° 17′=34600 :: 25′ 45″ : 27′ 20″.

12) By decimal calculation, 27′ 20″×32° 49′=1° 30′.

13) 22° 30′+1° 30′=24° 0′; which is the apparent side of the calculus.

14) There is no need here of any reduction, but only subtract 1° 30′ from the apparent north angle thus; 67° 45′−1° 30′=66° 15′, which is the apparent north angle of the calculus.

15) For *cd;*
Sine 41° 9′ 981824.
Sine 66° 15′ 986797.

Sine 37° 2′ 968621.

16) For *ad;*
Sine compl. 66° 15′ 1960503.
Tang. compl. 41° 9′ 1005854.

Tangent 19° 23′ 954649.

17) For *bc* subtract thus; 24° 0′ −19° 23′=4° 37′.
Sine compl. 37° 2′ 990216.
Sine compl. 4° 37′ 999858.

Sine compl. 37° 17′ 990074.

18) For the angle *bca* we have the proportion; as 37° 17′, the side now found, to 66° 15′, the apparent north angle of the calculus, so is 24° 0′, the apparent side of the calculus, to the angle required.
Sine 24° 0′ 960931.
Sine 66° 15′ 996159.

1957090.
Sine 37° 17′ 978229.

Sine 37° 56′ 978861.

Thus we have the side *bc*=37° 17′, and the angle *bca*=37° 56′.

We must now find the side and angle about the south pole.

19) For the complement of the side *oc;* 41° 9′−14° 37′=26° 32′.

20) By decimal calculation, 27′ 20″×26° 32′=1° 12′.

21) Here there is no need of reduction.

22) But add 1° 12′ to the true south angle thus; 131° 15′+1° 12′=132° 27′, which is the apparent south angle of the calculus, at the west, of which the complement is 47° 33′.

23) For *nc;*
Sine 41° 9′ 981824.
Sine 47° 33′ 986797.

Sine 29° 3′ 968621.

24) For *nh;*
Sine compl. 47° 33′ 1982926.
Tang. compl. 41° 9′ 1005854.

Tangent 30° 22′ 977072.

25) For the side *gc* first subtract; 30° 32′−24° 0′=6° 32′.

Sine compl. 29° 3′ 994161.
Sine compl. 6° 32′ 999717.

Sine compl. 29° 43′ 993878.

Its complement gives the required side *gc*=150° 17′.

26) For the angle *gch* we have the proportion; as 29° 43′, the side already found, to 47° 33′, the complement of the apparent south angle, so is 24° 0′, the apparent side of the calculus, to the angle required.

Sine 24° 0′ 960931.
Sine 47° 33′ 986797.

1947728.
Sine 29° 43′ 969523.

Sine 37° 15′ 978205.

Thus we have the side *gc*=150° 17′, and the angle *gch*=37° 15′.

27) 37° 17′ 37° 56′
150° 17′ 37° 15′

187° 34′ : 75° 1′ :: 37° 17′ : 14° 48′.

28) If 14° 48′ be subtracted from the angle 37° 56′, there remains the declination west 23° 8′.

XXII.

Calculation of the Magnetic Declination for the year 1780, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London 2° 25′.

1) 1780−1720=60; thus 60 years intervene; hence 60°×56′ =56° 0′.

2) Subtract these degrees and add the longitude thus; 112°+2° 25′−56°=58° 25′, which is the true north angle at the west.

3) For *pa;*
90°−58° 25′=31° 35′.

Sine 22° 30′ 958284.
Sine 58° 25′ 971911.

Sine 11° 34′ 930195.

4) For the south pole multiply as above; 60°×20′=20°.

5) Subtract 20° 0′, and add the east longitude thus; 145° 30′+2° 25′−20° 0′=127° 55′, which is the true south angle, at the west.

6) For *oh;*
127° 55′−90°=37° 55′.
Sine 22° 30′ 958284.
Sine 37° 55′ 978853.

Sine 13° 36′ 937137.

7) For *pc;*
41° 9′−11° 34′=29° 35′.

8) 29° 35′×6″=2′ 57″.

9) Hence 22′ 30″+2′ 57″=25′ 27″.

10) For *po;*
180°+13° 36′−11° 34′=182° 2′.

11) The square of 180°=32400: the square of 182° 2′=33024 :: 25′ 27″ : 26′ 0″.

12) By decimal calculation, 26′ × 29° 35′=1° 17′.

13) 22° 30′+1° 17′=23° 47′, which is the apparent side of the calculus.

14) There is no need of reduction at this latitude, but from the true north angle subtract 1° 17′ thus; 58° 25′−1° 17′=57° 7′; which therefore is the apparent south angle of the calculus, at the west.

15) For *cd;*
Sine 41° 9′ 981824.
Sine 57° 7′ 992416.

Sine 33° 33′ 974240.

16) For *ad;*
Sine compl. 57° 7′ 1973474.
Tang. compl. 41° 9′ 1005854.

Tangent 25° 23′ 9767620.

17) For *bc* first subtract thus: 25° 23′−23° 47′=1° 36′.
Sine compl. 33° 33′ 992085.
Sine compl. 1° 36′ 999983.

Sine compl. 33° 35′ 992068.

18) For the angle *bca* we have the proportion: as 33° 35′, the side already found, to 57° 7′, the apparent north angle, so is 23° 47′, the apparent side of the calculus, to the angle required.
Sine 23° 47′ 960560.
Sine 57° 7′ 992416.

1953976.
Sine 33° 35′ 974284.

Sine 38° 48′ 979692.

Thus we have the side *bc*=33° 35′, and the angle *bca*=38° 48′.

We must now find the side and angle about the north pole.

19) For the complement of the side *oc;* 41° 9′−13° 36′=27° 33′.

20) By decimal calculation, 26′ × 27° 33′=1° 11′.

21) Here there is no need of reduction.

22) But simply add 1° 11′ to the true south angle thus; 127° 55′+1° 11′=129° 6′, which is the apparent south angle of the calculus, at the west; of which the complement is 50° 54′.

23) For *nc;*
Sine 41° 9′ 981824.
Sine 50° 54′ 988988.

Sine 30° 43′ 970812.

24) For *nh;*
Sine compl. 50° 54′ 1979980.
Tang. compl. 41° 9′ 1005854.

Tangent 28° 51′ 974126.

25) For the side *gc* first subtract thus: 28° 51′−23° 47′= 5° 4′.
Sine compl. 30° 43′ 993435.
Sine compl. 5° 4′ 999829.

Sine compl. 31° 6′ 993264.

Its complement gives the side *cg*=148° 54′.

26) For the angle *gch* we have the proportion; as 31° 6′, the side now found, to 50° 54′, the complement of the apparent south angle; so is 23° 47′, the apparent side of the calculus, to the angle required.

Sine 23° 47′ 960560.
Sine 50° 54′ 988988.

1949548.
Sine 31° 6′ 971309.
Sine 37° 17′ 978239.

Thus we have the side $gc=148°$ 54′, and the angle $gch=37°$ 17′.

27) 33° 35′ 38° 48′
148° 54′ 37° 17′

182° 29′ : 76° 5′ :: 33° 35′ : 13° 54′.

28) If 13° 54′ be subtracted from 38° 48′, there remains the declination west, 24° 54′.

XXIII.

I will now arrange the declinations which have been found by experiments at London and Paris, and those which we have derived from the foregoing calculations; so that we may be able to compare them together, and see at one view the whole series of declinations, particularly those at Paris, from the year 1610 to the year 1680. And since, by the same calculus, I have ascertained the subsequent declinations down to the year 1920, I will subjoin these also: nor do I see any reason to doubt that experience will favor them; inasmuch as the calculus is based not only upon theory, but also upon experience itself. I am not indeed vain enough to put forth these speculations, without the sanction and consent of experience; for unless experience impart her light to theory, the latter will only blind the understanding, and cause it to wander in the mazes of error.

Declinations found at London.

Years.	Calculation.	Observations.
1722	14° 23′ West	14° 22′ West
1700	8° 14′	8° 0′
1792	6° 15′	6° 0′
1735	17° 46′	

Declinations found at Paris.

Years.	By Calculation. Deg.	Min.	By Experiments. Deg.	Min.
1610	8	18 East	8	0 East
1611	8	6	There are no	
1612	7	54	experiments	
1613	7	42	for these years.	
1614	7	30	There are no	
1615	7	19	experiments	
1616	7	8	for these years.	
1617	6	57		

Years.	By Calculation.		By Experiments.	
	Deg.	Min.	Deg.	Min.
1618	6	45	There are no experiments for these years.	
1619	6	33		
1620	6	22		
1621	6	15		
1622	6	8		
1623	6	1		
1624	5	55		
1625	5	49		
1626	5	43		
1627	5	37		
1628	5	31		
1629	5	25		
1630	5	19		
1631	5	9		
1632	5	0		
1633	4	50		
1634	4	40		
1635	4	29		
1636	4	19		
1637	4	9		
1638	3	59		
1639	3	48		
1640	3	36	3	0 East
1641	3	28		
1642	3	20		
1643	3	12		
1644	3	5		
1645	2	57		
1646	2	50		
1647	2	43		
1648	2	36		
1649	2	29		
1650	2	21		
1651	2	10		
1652	1	59		
1653	1	48		
1654	1	37		
1655	1	26		
1656	1	15		
1657	1	4		
1658	0	53		
1659	0	42		
1660	0	31		
1661	0	20		
1662	0	10		
1663	0	—		
1664	0	10 West	0	40 East
1665	0	20		
1666	0	32	0	0
1667	0	47		
1668	1	3		
1669	1	19		
1670	1	35	1	30 West
1671	1	46		
1672	1	58		
1673	2	10		
1674	2	21		
1675	2	33		
1676	2	46		
1677	2	57		
1678	3	7		
1679	3	18		
1680	3	29	2	40
1681	3	41	2	30
1682	3	53		
1683	4	5	3	50
1684	4	17	4	10
1685	4	29	4	10
1686	4	41	4	30
1687	4	53		
1688	5	5		
1689	5	17		
1690	5	30		
1691	5	41		
1692	6	1	5	50
1693	6	17	6	20
1694	6	34		
1695	6	51	6	48
1696	7	7	7	8
1697	7	24		
1698	7	40	7	40
1699	7	56	8	10

	By Calculation.		By Experiments.	
Years.	Deg.	Min.	Deg.	Min.
1700	8	12	8	12
1701	8	26	8	25
1702	8	39	8	48
1703	8	53	9	6
1704	9	6	9	20
1705	9	20	9	35
1706	9	33	9	48
1707	9	47	10	10
1708	10	1	10	15
1709	10	15	10	15
1710	10	28	10	50
1711	10	42	10	50
1712	10	56	11	15
1713	11	10	11	12
1714	11	24	11	30
1715	11	38	11	10
1716	11	52	12	20
1717	12	6	12	20
1718	12	20	12	30
1719	12	34	12	30
1720	12	48	13	0
1721	13	3	13	0
1722	13	18	13	0
1723	13	33	13	0
1724	13	48	13	0
1725	14	3	13	15
1726	14	18	13	45
1727	14	33	14	0
1728	14	48	14	0
1729	15	2		
1730	15	17		
1731	15	30		
1732	15	43		
1733	15	56		
1734	16	9		
1735	16	22		
1736	16	35		
1737	16	48		
1738	17	1		
1739	17	14		
1740	17	27		
1741	17	40		
1742	17	53		
1743	18	5		
1744	18	17		
1745	18	29		
1746	18	41		
1747	18	53		
1748	19	5		
1749	19	17		
1750	19	29		
1751	19	42		
1752	19	55		
1753	20	8		
1754	20	21		
1755	20	34		
1756	20	46		
1757	20	58		
1758	21	10		
1759	21	22		
1760	21	34		
1761	21	44		
1762	21	54		
1763	22	4		
1764	22	13		
1765	22	23		
1766	22	31		
1767	22	40		
1768	22	49		
1769	22	58		
1770	23	8		
1771	23	19		
1772	23	30		
1773	23	41		
1774	23	52		
1775	24	3		
1776	24	14		
1777	24	24		
1778	24	34		
1779	24	44		
1780	24	54		
1781	25	5		

Years.	By Calculation.	
	Deg.	Min.
1782	25	5
1783	24	58
1784	24	48
1785	24	40
1786	24	30
1787	24	20
1789	24	12
1790	24	2
1791	23	56
1792	23	50
1793	23	44
1794	23	38
1795	23	32
1796	23	26
1797	23	20
1798	23	14
1799	23	8
1800	23	3
1801	22	50
1802	22	34
1803	22	16
1804	21	54
1805	21	36
1806	21	18
1807	21	0
1808	20	42
1809	20	34
1810	20	12
1811	19	50
1812	19	25
1813	19	0
1814	18	38
1815	18	4
1816	17	30
1817	17	0
1818	16	30
1819	15	50
1820	15	19
1821	14	30
1822	13	50
1823	13	10
1824	12	30
1825	11	40
1826	10	50
1827	10	0
1828	9	10
1829	8	25
1830	7	38
1831	6	40
1832	5	50
1833	5	0
1834	4	10
1835	3	0
1836	2	2
1837	1	0
1838	0	0
1839	1	0 East
1840	2	0
1841	3	0
1842	4	0
1843	5	0
1844	6	0
1845	7	0
1846	8	0
1847	9	0
1848	10	0
1849	11	0
1850	12	4
1851	13	6
1852	14	9
1853	15	12
1854	16	15
1855	17	12
1856	18	0
1857	18	50
1858	19	45
1859	20	40
1860	21	32
1861	22	20
1862	23	0
1863	23	40
1864	24	20

Years.	By Calculation.	
	Deg.	Min.
1865	25	0
1866	25	40
1867	26	20
1868	27	0
1869	27	40
1870	28	18
1871	28	44
1872	29	10
1873	29	36
1874	30	2
1875	30	28
1876	30	54
1877	31	20
1878	31	56
1879	32	21
1880	32	45
1881	33	0
1882	33	20
1883	33	40
1884	33	55
1885	34	8
1886	34	20
1887	34	32
1888	34	42
1889	34	52
1890	35	4
1891	35	14
1892	35	23
1893	35	32
1894	35	40
1895	35	47
1896	35	52
1897	35	59
1898	36	6
1899	36	13
1900	36	21
1901	36	22
1902	36	23
1903	36	24
1904	36	25
1905	36	26
1906	36	27
1907	36	28
1908	36	29
1909	36	30
1910	36	31
1911	36	28
1912	36	25
1913	36	22
1914	36	19
1915	36	16
1916	36	13
1917	36	10
1918	36	7
1919	36	4
1920	36	0

The declinations thus follow in order according to the calculus, of which experience perhaps will be the test and confirmation. It is to be observed, that from this point the declination will again descend, and very gradually, through not less than 130 years, before it revisits the west; but in its ascent it will make very large and considerable strides. Hence it may be concluded, if only the calculation and experience are accordant, as I trust they are, that there is no certain annual progression of the declinations, but that at one time they pass annually through an entire degree, at another through scarcely a single minute; the difference consisting in the relation to the different situation of the poles. In other places, as for instance near the south and north poles, the annual declination describes still further degrees.

It is also to be observed, that the declinations at Paris can scarcely be greater than about 37 degrees, and this, very rarely; nor will the period when this is the case recur perhaps oftener than once in 20 or 30 ages.

With respect to the agreement between the observations and my own calculus, I find in some instances a difference of 35, 30, 20, 10, or 5 minutes, and in some cases no difference: but as no one save the observer himself can know in what way the declination was taken; in what way the meridian was found; whether or not it was in the most exact line and parallelism with the real meridian of the place; what sort of a magnet was used; what was the division of degrees; what the parallelism of the side of the instrument with the meridian line; whether ferruginous or magnetic particles were moving in the vicinity; whether the wind or air disturbed the tranquillity of the needle; whether the needle was moveable and horizontal upon its pivot, and had no hindrance, or tendency to stick fast; as no one can know all these circumstances, and yet all are possible, and in experimenting generally do occur, it is therefore impossible that the declinations calculated should coincide absolutely with the declinations observed. Let us now proceed to the calculation of the declinations in other places.

XXIV.

Calculation of the Magnetic Declination for the year 1670, *at Rome.*

North latitude 41° 50′; its complement 48° 20′.

Longitude east from London, 14° 13′.

1) 1720−1670=50: thus 50 years intervene; hence 50°×56′ =46° 40′.

2) Add these degrees together with the east longitude thus; 112° 0′+46° 40′+14° 13′=172° 53′, the true north angle towards the west.

3) For *pa;*

172° 53′−90°=82° 53.′

Sine 22° 40′ 958284.

Sine 82° 53′ 999664.

Sine 22° 19′ 957948.

4) For the south pole multiply as above; $50^\circ \times 20' = 16^\circ\ 40'$.

5) Add these degrees together with the east longitude thus; $145^\circ\ 30' + 16^\circ\ 46' + 14^\circ\ 13' = 176^\circ\ 23'$, which is the true south angle towards the west.

6) For *oh;*
$176^\circ\ 23' - 90^\circ = 86^\circ\ 23'$.

Sine 22° 30′ 958284.
Sine 86° 23′ 999913.

Sine 22° 27′ 958197.

7) For *pc;*
$48^\circ\ 10' + 22^\circ\ 19' = 70^\circ\ 29'$.

8) $70^\circ\ 29' \times 6'' = 7'\ 3''$.

9) Hence $22'\ 30'' + 7'\ 3'' = 29'\ 33''$.

10) For *po;*
$180^\circ + 22^\circ\ 19' - 22^\circ\ 27' = 224^\circ\ 46'$.

11) The square of $180^\circ = 32400$: the square of $224^\circ\ 46' = 50600 :: 29'\ 33'' : 46'\ 0.''$

12) By decimal calculation, $46' \times 70^\circ\ 29' = 5^\circ\ 24'$.

13) $22^\circ\ 30' + 5^\circ\ 24' = 27^\circ\ 54'$, which is the apparent side of the calculus.

14) At this latitude, of 41° 50′, there is need of reduction: it answers in the table to 44°; hence there will be the proportion, $60^\circ : 44^\circ :: 5^\circ\ 24' : 3^\circ\ 58'$.

Subtract 3° 58′ from the true north angle thus; $172^\circ\ 53' - 3^\circ\ 58' = 168^\circ\ 55'$, which is the apparent north angle of the calculus situated at the west, of which the complement is 11° 5′.

15) For *cd;*

Sine 48° 10′ 987220.
Sine 11° 5′ 928383.

Sine 8° 14′ 915603.

16) For *ad;*

Sine compl. 11° 5′ 1999182.
Tang. compl. 48° 10′ 995189.

Tangent 47° 38′ 1003993.

17) For the side *bc* first add thus; $47^\circ\ 38' + 27^\circ\ 54' = 75^\circ\ 32'$.

Sine compl. 8° 14′ 999550.
Sine compl. 75° 32′ 939762.

Sine compl. 75° 41′ 939312.

18) For the angle *bca* we have the proportion, as 75° 41′, or the side now found, to 11° 5′, the complement of the apparent north angle, so is 27° 54′, the apparent side of the calculus, to the angle required.

Sine 27° 54′ 966802.
Sine 11° 5′ 928383.

1895185.
Sine 75° 41′ 998629.

Sine 5° 18′ 896556.

Thus we have the side $bc = 75^\circ\ 41'$; and the angle $bca = 5^\circ\ 18'$.

We must now find the side and angle at the south pole.

19) For the complement of the side *oc;* $48^\circ\ 10' - 22^\circ\ 27' = 25^\circ\ 43'$.

20) By decimal calculation, $46' \times 25^\circ\ 43' = 1^\circ\ 57'$.

21) Make here the reduction as above, $60^\circ : 44^\circ :: 1^\circ\ 57' : 1^\circ\ 26'$.

22) Add 1° 26′ to the true south angle thus; $176^\circ\ 23' + 1^\circ\ 26' = 177^\circ\ 49'$, which is the apparent

south angle of the calculus, situated at the west, of which the complement is 2° 11′.

23) For nc;

Sine 48° 10′ 987220.
Sine 2° 11′ 858089.

Sine 1° 38′ 845309.

24) For nh;

Sine compl. 2° 11′ 1999968.
Tang. compl. 48° 10′ 995189.

Tangent 48° 9′ 1004779.

25) For the side gc first subtract thus; 48° 9′ − 27° 54′ = 20° 15′.

Sine compl. 1° 38′ 999982.
Sine compl. 20° 15′ 997229.

Sine compl. 20° 19′ 997211.

Its complement gives the side gc = 159° 41′.

26) For the angle gch there will be the proportion, as 20° 19′, or the side already found, to 2° 11′, or the complement of the apparent south angle, so is 27° 54′, or the apparent side of the calculus, to the angle required.

Sine 27° 54′ 966802.
Sine 2° 11′ 858089.

1824891.
Sine 20° 19′ 954059.

Sine 2° 55′ 870832.

Thus we have the side gc = 159° 41′, and the angle gch = 2° 55′.

27) 75° 41′ 5° 18′
159° 51′ 2° 55′

235° 22′ : 8° 13′ :: 75° 41′ : 2° 38′.

28) If 2° 38′ be subtracted from 5° 18′, there remains declination west, 2° 40′.

According to observations, the declination was 2° 30′; whence there is a difference of only 0° 10′, as compared with Muschenbroek. Auzoutius observed at Rome, in the year 1670, that the declination was either 2° or 2° 30′ towards the west; as recorded in the *Philosophical Transactions*, n. 58. But Rome lies 11° 48′ east of Paris; so that the declination towards the west was greater at Rome, than during the same year at Paris.

XXV.

Calculation of the Magnetic Declination for the year 1672, *at Uraniborg.*

North latitude 55° 54′; its complement 34° 6′.

Longitude east from London, 13° 0′.

1) 1720 − 1672 = 48; thus 48 years intervene; and 48 × 56′ = 44° 48′.

2) Add 44° 48′ together with the east longitude thus; 112° 0′ + 13° 0′ + 44° 48′ = 169° 48′, which is the true north angle situated at the west.

3) For pa;
169° 48′ − 90° = 79° 48′.

Sine 22° 30′ 958284.
Sine 79° 48′ 999308.

Sine 20° 38′ 957592.

4) For the south pole multiply as above thus; 48° × 20′ = 16° 0′.

5) Add these degrees, 16° 0′, together with the east longitude, thus; 145° 30′ + 16° 0′ + 13° 0′ = 174° 30′.

6) For *oh;*
174° 30′ − 90° = 84° 30′.
Sine 22° 30′ 958284.
Sine 84° 30′ 999709.

Sine 20° 49′ 957993.

7) For *pc;*
34° 6′ + 20° 38′ = 54° 44′.

8) 54° 44′ × 6″ = 5′ 30″.

9) 22′ 30″ + 5′ 30″ = 28′ 0″.

10) For *po;*
180° + 20° 38′ + 20° 49′ = 221° 27′.

11) The square of 180 = 32400 : the square of 221° 27′ = 49040 :: 28′ : 42′ 20″.

12) By decimal calculation, 42′ 20″ × 54° 44′ = 3° 53′.

13) 22° 30′ + 3° 53′ = 26° 23′, which is the apparent side of the calculus.

14) Make the reduction or increase, according to the table at this latitude, 60 : 77 :: 3° 53′ : 4° 59′.

Subtract 4° 59′ from the true north angle or arc; 169° 48′ − 4° 59′ = 164° 49′; which is the apparent north angle or arc of the calculus, at the west; of which the complement is 15° 11′.

15) For *cd;*
Sine 34° 6′ 974868.
Sine 15° 11′ 941815.

Sine 8° 27′ 916683.

16) For *ad;*
Sine compl. 15° 11′ 1998453.
Tang. compl. 34° 6′ 1016937.

Tangent 33° 9′ 981516.

17) For the side *bc* first add; 33° 9′ + 26° 23′ = 59° 32′.
Sine compl. 8° 27′ 999526.
Sine compl. 59° 32′ 970504.

Sine compl. 59° 54′ 970030.

18) For the angle *bca* we have the proportion, as 59° 54′, or the side already found, to 15° 11′, the complement of the apparent north arc, so is 26° 23′, the apparent side of the calculus, to the angle required.
Sine 26° 23′ 964775.
Sine 15° 11′ 941815.

1906590.
Sine 59° 54′ 993709.

Sine 7° 44′ 912881.

Thus we have the side *bc* = 59° 54′, and the angle *bca* = 7° 44′.

We must now find the side and angle at the south pole.

19) For the complement of the side *oc;* 34° 6′ − 20° 49′ = 13° 27′.

20) By decimal calculation, 42′ 20″ × 13° 17′ = 0° 54′.

21) Make the reduction or increase, 60 : 77 :: 0° 54′ : 1° 9′.

22) Add 1° 9′ to the true south arc, 174° 30′ + 1° 9′ = 175° 39′, which is the apparent south arc of the calculus, situated at the west, of which the complement is 4° 21′.

23) For *nc* ;

Sine 34° 6′ 974868.
Sine 4° 21′ 887995.

Sine 2° 26′ 862863.

24) For *nh* ;

Sine compl. 4° 21′ 1999874.
Tang. compl. 34° 6′ 1016937.

Tangent 34° 1′ 982937.

25) For the side *gc* first subtract thus; 34° 1′−26° 23′=7° 38′.

Sine compl. 2° 26′ 999961.
Sine compl. 7° 38′ 999613.

Sine compl. 8° 1′ 999574.

Its complement gives the side *gc*=171° 59′.

26) For the angle *gch* we have the proportion, as 8° 1′, or the side now found, to 4° 21′, the complement of the apparent south arc, so is 26° 23′, or the apparent side of the calculus, to the angle required.

Sine 26° 23′ 964775.
Sine 4° 21′ 887995.

1852770.
Sine 8° 1′ 914445.

Sine 13° 59′ 938325.

Thus we have the side *gc*=171° 59′, and the angle *gch*=13° 59′.

27) 59° 54′ 7° 44′
171° 59′ 13° 59′

231° 53′ : 21° 43′ :: 59° 54′ : 5° 36′.

28) If 5° 36′ be subtracted from 7° 44′, there remains the declination west, 2° 8′.

The observation in Tab. VI. indicates the declination in that year to have been 2° 35′; whence there is a difference of 0° 27′.

XXVI.

On a voyage to Hudson's Straits in the years 1721 *and* 1725; *longitude west from London,* 41° 0′; *north latitude,* 55° 0′.

The north latitude is 55° 0′; its complement 35° 0′; west longitude 41° 0′.

1) 1725−1720=5; thus five years intervene; hence 5°×56′=4° 40′.

2) Subtract these degrees, and likewise the longitude (since it is west); 112° 0′−4° 40′−41° 0′=66° 20, which is the true north angle.

3) For *pa* ;

90°−66° 20′=23° 40′.

Sine 22° 30′ 958284.
Sine 23° 40′ 960359.

Sine 8° 50′ 918643.

4) For the south pole multiply as above; whence 5°×20′=1° 40′.

5) Subtract 1° 40′, together with the west longitude thus; 145° 30′−1° 40′−41° 0′=102° 50′,

which is the true south angle, to the west.

6) For *oh;*
$102^\circ\ 50'-90^\circ=12^\circ\ 50'$.

Sine 22° 30′ 958284.
Sine 12° 50′ 934658.

Sine 4° 53′ 892942.

7) For *pc;*
$35^\circ\ 0'-8^\circ\ 50'=26^\circ\ 10'$.

8) $26^\circ\ 10'\times 6''=2'\ 36''$.

9) $22'\ 30'+2'\ 36=25'\ 6''$.

10) For *po;*
$180^\circ-8^\circ\ 50'-4^\circ\ 53'=166^\circ\ 17'$.

11) The square of $180=32400$: the square of $166^\circ\ 17'=27000::25'\ 6'':21'\ 0''$.

12) By decimal calculation, $21'\ 0''\times 26^\circ\ 10'=0^\circ\ 54'$.

13) $22^\circ\ 30'+0^\circ\ 54'=23^\circ\ 24'$, which is the apparent side of the calculus.

14) Make the reduction or increase at this latitude; $60^\circ:74^\circ::8^\circ\ 54':1^\circ\ 6'$. Hence subtract 1° 6′ from the true north angle; $66^\circ\ 20'-1^\circ\ 6'=65^\circ\ 14'$, which is the apparent north angle of the calculus, situated at the west.

15) For *cd;*

Sine 35° 0′ 975859.
Sine 65° 14′ 995809.

Sine 31° 23′ 971668.

16) For *ad;*

Sine compl. 65° 14′ 1962213.
Tang. compl. 35° 0′ 1015477.

Tangent 16° 21′ 946736.

17) For *bc* first subtract; $23^\circ\ 24'-16^\circ\ 21'=7^\circ\ 3'$.

Sine compl. 31° 23′ 993130.
Sine compl. 7° 3′ 999670.

Sine compl. 32° 6′ 992800.

18) For the angle *bca* we have the proportion, as 32° 6′, the side now found, to 65° 14′, the apparent north angle, so is 23° 24′, the apparent side of the calculus, to the angle required.

Sine 23° 24′ 959895.
Sine 65° 14′ 995809.

1955704.
Sine 32° 6′ 972542.

Sine 42° 44′ 983162.

Thus we have the side $bc=32^\circ\ 6'$, and the angle $bca=42^\circ\ 44'$. We must now find the side and angle at the south pole.

19) For the complement of the side *oc;* $35^\circ\ 0'-4^\circ\ 53'=30^\circ\ 7'$.

20) By decimal calculation, $21'\ 0''\times 30^\circ\ 7'=1^\circ\ 3'$.

21) Make the reduction or increase; $60^\circ:74^\circ::1^\circ\ 3':1^\circ\ 17'$.

22) Add 1° 17′ to the true south angle; $102^\circ\ 50'+1^\circ\ 17'=104^\circ\ 7'$, which is the apparent south angle of the calculus, situated at the west; of which the complement is 75° 53′.

23) For *nc;*

Sine 35° 0′ 975859.
Sine 75° 53′ 998668.

Sine 33° 48′ 974527.

24) For *nh;*

Sine compl. 75° 53′ 1938720.
Tang. compl. 35° 0′ 1015477.

Tangent 9° 42′ 923243.

25) For the side *gc* first subtract; 23° 24′−9° 42′=13° 42′.

Sine compl. 33° 48′ 991959.
Sine compl. 13° 42′ 998746.

Sine compl. 36° 10′ 990705.

Its complement gives the side *gc* =143° 50′.

26) For the angle *gch* we have the proportion, as 36° 10′, the side now found, to 75° 53′, the complement of the apparent south angle, so 23° 54′, the apparent side of the calculus, to the angle required.

Sine 23° 24′ 959895.
Sine 75° 53′ 998668.

1958563.
Sine 36° 10′ 977095.

Sine 40° 44′ 981468.

Thus we have the side *gc*=143° 50′, and the angle *gch*=40° 44′.

27) 32° 6′ 42° 44′
143° 50′ 40° 44′

175° 56′ : 83° 28′ :: 32° 6′ : 15° 11′.

28) If 15° 11′ be subtracted from 42° 44′, there remains the declination west, 27° 33′.

According to the observations in Table XII., the declination seems to have been 28° 15′; whence there is a difference of 0° 42′, which may easily be accounted for at sea, especially as the true year is not given.

XXVII.

Calculation of the Magnetic Declination at the Sebald Islands, at the eastern entrance into the Straits of Magellan, in the year 1707.

South latitude 52° 0′; its complement 38° 0′.

Longitude west from London 70°.

1) 1720−1707=13; thus 13 years intervene: hence 13°×56′ =12° 8′.

2) Add these degrees, and subtract the longitude; 112° 0′+12° 8′−70°=54° 8′, which is the true north angle at the west.

3) For *pa;*
90°−54° 8′=35° 52′.
Sine 22° 30′ 958284.
Sine 35° 52′ 976782.

Sine 12° 57′ 935066.

4) For the south pole multiply as above thus; 13°×20′=4° 20′.

5) Add 4° 20, but subtract the longitude thus; 145° 30′+4° 20′ −70°=79° 50′, which is the true south angle at the west.

6) For *oh;*
90°−79° 50′=10° 10′.
Sine 22° 30′ 958284.
Sine 10° 10′ 924677.

Sine 3° 52′ 882961.

7) For *pc;*
52°+90°−12° 57′=129° 3′.

8) 129° 3′×6″=12′ 54″.

9) 22′ 30″+12′ 54″=35′ 24′.

10) For *po;*
$180^\circ - 12^\circ\ 57' - 3^\circ\ 52' = 163^\circ\ 11'$.

11) The square of $180^\circ = 32000$: the square of $163^\circ\ 11' = 26580 :: 35'\ 24'' : 29'\ 0''$.

12) By decimal calculation, $29'\ 0'' \times 129^\circ\ 3' = 6^\circ\ 14'$.

13) $22^\circ\ 30' + 6^\circ\ 14' = 28^\circ\ 44'$, which is the apparent side of the calculus.

14) Make the reduction or increase, $60^\circ : 67^\circ :: 6^\circ\ 14' : 6^\circ\ 57'$. Subtract these degrees from the true north angle thus; $54^\circ\ 8' - 6^\circ\ 57' = 47^\circ\ 11'$; which gives the apparent north angle of the calculus situated at the west.

15) For *cd;*
Sine 38° 0′ 978934.
Sine 47° 11′ 986542.

Sine 26° 50′ 965476.

16) For *ad;*
Sine compl. 47° 11′ 1983228.
Tang. compl. 38° 0′ 1010719.

Tangent 27° 58′ 972509.

17) For the side *bc* first add thus; $27^\circ\ 58' + 28^\circ\ 27' = 56^\circ\ 25'$. By logarithms:

Sine compl. 26° 50′ 995052.
Sine compl. 56° 25′ 974284.

Sine compl. 60° 26′ 969336.

Its complement gives the side $bc = 119^\circ\ 34'$.

18) For the angle *bca* we have the proportion; as 60° 26′, the side already found, to 47° 11′, the apparent north angle, so is 28° 27′, or the apparent side of the calculus, to the angle required.

Sine 28° 27′ 967796.
Sine 47° 11′ 986542.

1954338.
Sine 60° 26′ 993941.

Sine 23° 41′ 960397.

Thus we have the side $bc = 119^\circ\ 34'$; and the angle $bca = 23^\circ\ 41'$.

We must now find the side and angle at the south pole.

19) For the side *oc;*
$90^\circ\ 0' + 52^\circ\ 0' + 3^\circ\ 52' = 145^\circ\ 52'$.

20) By decimal calculation, $29'\ 0'' \times 145^\circ\ 52' = 7^\circ\ 3'$.

21) Make the reduction or increase, $60^\circ : 67^\circ :: 7^\circ\ 3' : 7^\circ\ 52'$.

22) Add 7° 52′ to the true south angle; $79^\circ\ 50' + 7^\circ\ 52' = 87^\circ\ 42'$, which is the apparent south angle of the calculus at the west.

23) For *nc;*
Sine 38° 0′ 978934.
Sine 87° 42′ 999965.

Sine 37° 58′ 978899.

24) For *nh;*
Sine compl. 87° 42′ 1860348.
Tang. compl. 38° 0′ 1010719.

Tangent 1° 48′ 849629.

25) For the side *gc* first subtract; $28^\circ\ 27' - 1^\circ\ 48' = 26^\circ\ 39'$. By logarithms:
Sine compl. 37° 58′ 989673.
Sine compl. 26° 39′ 995122.

Sine compl. 45° 12′ 984795.

26) For the angle *gch* we have the proportion; as 45° 12′, the side already found, to 87° 42′, the apparent south angle of the calculus, so is 28° 27′, the apparent

side of the calculus, to the angle required.

Sine 28° 27′ 967796.
Sine 87° 42′ 999965.
1967761.
Sine 45° 12′ 985099.
Sine 42° 8′ 982662.

Thus we have the side gc=45° 12′, and the angle gch=42° 8′.

27) 119° 34′ 23° 41′
45° 12′ 42° 8′
164° 46′ : 65° 49′ :: 119° 34′ : 47° 47′.

28) If 23° 41′ be subtracted from 47° 47′, there remains the declination west, 24° 6′.

According to observations, in the years 1706, 1707, and 1708, (Tab. XXIV. XXV. XIV.,) the declination seems to have been east 23° 0′ : 23° 5′, at Sebald's Islands.

But it is to be observed that Feuillè, in Tab. XIV., for the year 1708, states the declination to be east 23° 0′, at south latitude 53°, but at longitude 315° 29′ from Teneriffe, or about 66° from London; with which longitude also the declination 23° 0′ coincides, but nearer towards the entrance the declination is greater; according to the calculus, 24° 6′.

Verune observed, (Tab. XXIV.,) in the year 1706, at south latitude 52° 19′, and west longitude 70°, or 69½°, that the declination was about 23°, which also nearly agrees with our calculation.

In Dampier's voyage, (Tab. XXV.,) in the year 1707, near the Waard Islands, the declination was found to be 23° 0′, but at south latitude 51° 25′; with which also coincides 23° 0′, but at a higher latitude, for instance, at 52° 0, as in the calculus, it will be greater, and in fact about 24°.

John Baptista Homann and others, place the Sebald Islands in their geographical maps, at longitude west from London, about 70° or 69½°, but at latitude 51°; with which coincides the declination 23° 0′; but at latitude 52° 0′, it will be 24° 0′.

In order then that the true place of the observation may be obtained, the latitude must be 51° south, and the longitude about 69°; with which the declination 23° will evidently coincide, according to the calculus.

XXVIII.

Calculation of the Magnetic Declination at the Cape of Good Hope, for the year 1600.

South latitude 35° 0′; its complement 55° 0′.

Longitude east from London, about 20°.

1) 1720−1600=120: thus 120 years intervene: hence 120° × 56′ =112° 0′.

2) Add these degrees to the

north angle at London, in the year 1720, together with the longitude (inasmuch as it is east) thus; 112° 0′+20° 0′+112° 0′=244°. Subtract 244° from 360°, and the remainder, 116°, is the true north angle placed at the east.

3) For *pa;*
116° 0′−90°=26° 0′.
Sine 22° 30′ 958284.
Sine 26° 0′ 964184.

Sine 9° 39′ 922468.

4) For the south pole multiply as above; 120°×20′=40°.

5) Add 40° together with the east longitude thus; 145° 30′+40° 0′+20° 0′=205° 30′. Subtract 205° 30′ from 360°; and the remainder, 154° 30′, is the true south angle situated at the east.

6) For *oh;*
154° 30′−90°=64° 30′.
Sine 22° 30′ 958284.
Sine 64° 30′ 995548.

Sine 20° 12′ 953832.

7) For *pc;*
35° 0′+90° 0′+9° 39′=134° 39′.

8) 134° 39′×6″=13′ 27″.

9) 22′ 30″+13′ 27″=35′ 57″.

10) For *po;*
180°+9° 39′+20° 12′=209° 51′.

11) The square of 180°=32400: the square of 209° 51′=44000 :: 35′ 57″ : 48′ 30″.

12) By decimal calculation, 48′ 30″×134° 39′=10° 50′.

13) 22° 30′+10° 50′=33° 20′, which is the apparent side of the calculus.

14) Make the reduction for this latitude; 60° : 30° :: 10°50′ : 5°25′; add 5° 25′ to the true north angle thus; 116° 0′+5° 25′=121° 25′; (the addition being made because the north pole is now on the east,) which is the apparent north angle of the calculus situated at the east; its complement is 58° 35′.

15) For *cd;*
Sine 55° 0′ 991336.
Sine 58° 35′ 993115.

Sine 44° 21′ 984451.

16) For *ad;*
Sine compl. 58° 35′ 1971705.
Tang. compl. 55° 0′ 984522.

Tangent 36° 40′ 987183.

17) For the side *bc* first subtract; 36° 40′−33° 20′=3° 20′. By logarithms:
Sine compl. 44° 21′ 985435.
Sine compl. 3° 20′ 999926.

Sine compl. 44° 27′ 985361.

Its complement gives the side in question, 135° 33′.

18) For the angle *bca* we have the proportion; as 44° 27′, the side now found, to 58° 35′, the complement of the apparent north angle, so is 33° 20′, the apparent side of the calculus, to the angle required.

Sine 33° 20′ 973997.
Sine 58° 35′ 993115.

1967112.
Sine 44° 27′ 984527.

Sine 42° 2′ 982585.

Thus we have the side bc=135° 33′; and the angle bca=42° 2′.

We must now find the side and angle at the south pole.

19) For the side oc;
90° 0′+35° 0′−20° 12′=104° 48′.

20) By decimal calculation, 48′ 30″ × 104° 48′=8° 24′.

21) Make the reduction according to the table, at this latitude, 60° : 30° :: 8° 24′ : 4° 12′.

22) Subtract 4° 12′ from the true south angle, 154° 30′−4° 12′ =150° 18′, which is the apparent south angle of the calculus situated at the west, of which the complement is 29° 42′.

23) For nc;
Sine 55° 0′ 991336.
Sine 29° 42′ 969500.
Sine 23° 57′ 960836.

24) For nh;
Sine 29° 42′ 1993883.
Sine 55° 0′ 984522.
Sine 51° 8′ 1009361.

25) For the side gc first add; 51° 8′+33° 20′=84° 28′.
Sine compl. 23° 57′ 996089.
Sine compl. 84° 28′ 898418.
Sine compl. 84° 57′ 894507.

26) For the angle bca we have the proportion; as 84° 57′, the side already found, to 29° 42′, the complement of the apparent south angle, so is 33° 20′, or the apparent side of the calculus, to the angle required.

Sine 33° 20′ 973997.
Sine 29° 42′ 969500.
1943497.
Sine 84° 57′ 999831.
Sine 15° 51′ 943666.

27) 135° 33′ 42° 2′
84° 57′ 15° 51′
220° 30′ : 57° 53′ :: 135° 33′ : 36° 19′.

28) If 36° 19′ be subtracted from 42° 2′, there remains the declination east, 5° 43′.

But some assert that in the year 1600, there was no declination at the Cape of Good Hope. Kircher, however, in Tab. I., states that 26 leagues from the Cape of Good Hope there was a declination east of 4° 0′; whether, therefore, observers have determined the true year or not, is still doubtful.

XXIX.

Calculation of the Magnetic Declination for the year 1675, *at the Cape of Good Hope.*

South latitude 35° 0′; its complement 55° 0′.

Longitude east from London, about 20°.

1) 1720−1675=45: thus 45 years intervene; hence 45° × 56′= 42° 0′.

2) Add these degrees, together

with the longitude, which is east, thus; $112^\circ\ 0'+20^\circ\ 0'+42^\circ\ 0'=174^\circ\ 0'$, which is the true north angle situated at the west.

3) For *pa;*
$174^\circ\ 0'-90^\circ=84^\circ\ 0'$.
Sine 22° 30′ 958284.
Sine 84° 0′ 999761.
Sine 22° 22′ 958045.

4) For the south pole multiply as above; $45^\circ\times 20'=15^\circ\ 0'$.

5) Add these degrees, together with the longitude; $145^\circ\ 30'+20^\circ+15^\circ=180^\circ\ 30'$; which if subtracted from 360°, leaves 179° 30′, which is the true north angle, situated at the east.

6) For *oh;*
$179^\circ\ 30'-90^\circ=89^\circ\ 30'$.
Sine 22° 30′ 958284.
Sine 89° 30′ 999998.
Sine 22° 30′ 958282.

7) For *pc;*
$35^\circ\ 0'+90^\circ\ 0'+22^\circ\ 22'=147^\circ\ 22'$.

8) $147^\circ\ 22'\times 6''=14^\circ\ 44'$.

9) $22^\circ\ 30'+14^\circ\ 44'=37^\circ\ 14'$.

10) For *po;*
$180^\circ+20^\circ\ 22'+22^\circ\ 30'=224^\circ\ 52'$.

11) The square of $180=32400$: the square of $224^\circ\ 52'=50600$ :: $37'\ 14'' : 57'\ 47''$.

12) By decimal calculation, $57'\ 47''\times 147^\circ\ 22'=14^\circ\ 10'$.

13) $22^\circ\ 30'+14^\circ\ 10'=36^\circ\ 40'$, which is the apparent side of the calculus.

14) Make the reduction here according to the Table; $60^\circ : 30^\circ$ :: $14^\circ\ 10' : 7^\circ\ 5'$. Subtract these degrees (7° 5′) from the true north angle thus; $174^\circ\ 0'-7^\circ\ 5'=166^\circ\ 55'$, which is the apparent north angle of the calculus, situated at the west, of which the complement is 13° 5′.

15) For *cd;*
Sine 55° 0′ 991336.
Sine 13° 5′ 935481.
Sine 10° 41′ 926817.

16) For *ad;*
Sine compl. 13° 5′ 1998857.
Tang. compl. 55° 0′ 984522.
Tangent 54° 17′ 1014335.

17) For the side *bc* first subtract thus; $54^\circ\ 17'-36^\circ\ 40'=17^\circ\ 37'$.
Sine compl. 10° 41′ 999240.
Sine compl. 17° 37′ 997914.
Sine compl. 20° 31′ 997154.

Its complement gives the side $bc=159^\circ\ 29'$.

18) For the angle *bca* we have the proportion, as 20° 31′, the side now found, to 13° 5′, the complement of the apparent north angle, so is 36° 40′, or the apparent side of the calculus, to the angle required.
Sine 36° 40′ 977609.
Sine 13° 5′ 935481.
1913090.
Sine 20° 31′ 954466.
Sine 21° 43′ 958624.

Thus we have the side $bc=159^\circ\ 29'$, and the angle $bca=21^\circ\ 43'$.

We must now find the side and angle at the south pole.

19) For the side *oc;*
$35^\circ\ 0'+90^\circ\ 0'-22^\circ\ 30'=102^\circ\ 30'$.

20) By decimal calculation, 57′ 47″ × 102° 30′ = 9° 50′.

21) At this latitude make the proper reduction, 60° : 30° :: 9° 50′ : 4° 55′.

22) Subtract 4° 55′ from the true south angle, as the pole is at the east side; 179° 30′ − 4° 55′ = 174° 35′, which is the apparent south angle of the calculus, situated at the east; its complement is 5° 25′.

23) For *nc*;

Sine 55° 0′ 991336.

Sine 2° 25′ 862496.

Sine 1° 59′ 853832.

24) For *nh*;

Sine compl. 2° 25′ 1999961.

Tang. compl. 55° 0′ 984522.

Tangent 54° 58′ 1015439.

25) For the side *gc* first add thus; 54° 58′ + 36° 40′ = 91° 38′; its complement is 88° 22′.

Sine compl. 1° 59′ 999974.

Sine compl. 88° 22′ 845489.

Sine compl. 88° 22′ 845463.

Its complement gives the side in question, 91° 38′.

26) For the angle *gch* we have the proportion, as 88° 22′, the side now found, to 5° 25′, the complement of the apparent north angle, so is 36° 40′, the apparent side of the calculus, to the angle required.

Sine 36° 40′ 977609.

Sine 5° 25′ 897496.

1875105.

Sine 88° 22′ 999982.

Sine 3° 14′ 875123.

Thus we have the side *gc* = 91° 38′, and the angle *gch* = 3° 14′.

27) 159° 29′ 21° 43′

91° 38′ 3° 14′ difference

251° 7′ : 18° 29′ :: 159° 29′ : 11° 44′.

28) If 11° 44′ be subtracted from 21° 43′, there remains the declination west, 9° 59′.

In Leydekker's Table XIII., the declination was observed, at east longitude 41° 14′ and at south latitude 38° 25′, to be 11° 30′; and in Tab. VI., on the promontory of Aguillas, near the Cape of Good Hope, at latitude 34° 50′, to be 8° 0′, in both cases in the year 1675: whence the declination seems to have been 9° 59′ at the Cape of Good Hope.

XXX.

Calculation of the Magnetic Declination for the year 1720, *at the Cape of Good Hope.*

South latitude 35° 0′; its complement 55° 0′.

Longitude east from London, about 20°.

1) No years intervene in this case.

2) Hence we have only to add the longitude, because it is east,

thus; $112^\circ\ 0'+20^\circ\ 0'=132^\circ\ 0$; which is the true north angle situated at the west.

3) $132^\circ\ 0'-90^\circ=42^\circ\ 0'$, for *pa*.

Sine 22° 30′ 958284.

Sine 42° 0′ 982551.

Sine 14° 50′ 940835.

4) In this case there is no need of multiplication for the south pole.

5) But only add the longitude, because it is east; $145^\circ\ 30'+20^\circ\ 0'=165^\circ\ 30'$, which is the true south angle situated at the west.

6) For *oh;*

$165^\circ\ 30'-90^\circ=75^\circ\ 30'$.

Sine 22° 30′ 958284.

Sine 75° 30′ 998594.

Sine 21° 45′ 956878.

7) For *pc;*

$35^\circ\ 0'+90^\circ\ 0'+14^\circ\ 50'=139^\circ\ 50'$.

8) $139^\circ\ 50'\times 6''=14^\circ\ 0'$.

9) $22'\ 30''+14'\ 0''=36'\ 30''$.

10) $180^\circ+14^\circ\ 50'+21^\circ\ 45'=216^\circ\ 35'$, for *po*.

11) The square of $180=32400$: the square of $216^\circ\ 35'=46800$ :: $36'\ 30''$: $52'\ 0''$.

12) By decimal calculation, $52^\circ\times 139^\circ\ 50'=12^\circ\ 8'$.

13) $22^\circ\ 30'+12^\circ\ 8'=34^\circ\ 38'$, which is the apparent side of the calculus.

14) Make here the proper reduction, $60^\circ : 30^\circ :: 12^\circ\ 8' : 6^\circ\ 4'$; and by subtracting 6° 4′ from the true north angle ($132^\circ\ 0'-6^\circ\ 4'=125^\circ\ 56'$), we have the apparent north angle of the calculus, situated at the west, of which the complement is 54° 4′.

15) For *cd;*

Sine 55° 0′ 991336.

Sine 54° 4′ 990832.

Sine 41° 33′ 982168.

16) For *ad;*

Sine compl. 54° 4′ 1976852.

Tang. compl. 55° 0′ 984522.

Tangent 39° 58′ 992330.

17) For the side *bc* first subtract; $39^\circ\ 58'-34^\circ\ 38'=5^\circ\ 20'$.

Sine compl. 41° 33′ 987412.

Sine compl. 5° 20′ 999811.

Sine compl. 41° 50′ 987223.

Its complement gives the side in question $bc=138^\circ\ 10'$.

18) For the angle *bca* we have the proportion, as 41° 50′, the side now found, to 54° 4′, the complement of the apparent north angle, so is 34° 38′, the apparent side of the calculus, to the angle required.

Sine 34° 38′ 975459.

Sine 54° 4′ 990832.

1966291.

Sine 41° 50′ 982410.

Sine 43° 38′ 983881.

Thus we have the side $bc=138^\circ\ 10'$, and the angle $bca=43^\circ\ 38'$.

We must now find the side and angle at the south pole.

19) For the side *oc;*

$125^\circ\ 0'-21^\circ\ 45'=103^\circ\ 15'$.

20) By decimal calculation, $52'\times 103^\circ\ 15'=8^\circ\ 55'$.

21) Make the reduction proper at this latitude, $60 : 30^\circ :: 8^\circ\ 55' : 4^\circ\ 28'$.

22) Add 4° 28′ to the true south angle; 165° 30′+4° 28′=169° 58″, which is the apparent south angle of the calculus, situated at the west; of which the complement is 10° 2′.

23) For *nc*;

Sine 55° 0′ 991336.
Sine 10° 2′ 924110.

Sine 8° 12′ 915446.

24) For *nh*;

Sine compl. 10° 2′ 1999330.
Tang compl. 55° 0′ 984522.

Tangent 54° 35′ 1014808.

25) For the side *gc* first add: 54° 35′+34° 38′=89° 13′.

Sine compl. 8° 12′ 999553.
Sine compl. 89° 13′ 813581.

Sine compl. 89° 13′ 813134.

26) For the angle *gch* we have the proportion, as 89° 13′, the side now found, to 10° 2′, the apparent south angle of the calculus, so is 34° 38′, or the apparent side of the calculus, to the angle required.

Sine 34° 38′ 975459.
Sine 10° 2′ 924140.

1899569.
Sine 89° 13′ 999995.

Sine 5° 41′ 899574.

Thus we have the side *gc*=89° 13′, and the angle *gch*=5° 41′.

27) 138° 10′ 43° 38′
89° 13′ 5° 41′

227° 23′ : 49° 19′ :: 138° 10′ : 29° 47′.

28) If 29° 47′ be subtracted from 43° 38′, there remains the declination west, 13° 51′.

From Tab. XVII. in the year 1718, at the Cape of Good Hope, the declination west seems to have been 14° 0′; whence there is a difference of 0° 9′.

END OF PART II.

THE PRINCIPIA.

PART III.

THE PRINCIPIA.

PART III.

CHAPTER I.

COMPARISON OF THE SIDEREAL HEAVEN WITH THE MAGNETIC SPHERE.

Nature is always the same, and always maintains the highest similarity to herself. If in the least things she is most perfectly geometrical, so also is she in the greatest. That which in a smaller form is most perfect generates nothing dissimilar to itself, and consequently there is nothing dissimilar to it in the larger. All dissimilarity implies imperfection. Were nature dissimilar to herself in her larger productions, there would be a something in her least productions which would be imperfect, and which would generate also what is dissimilar. But since in the first ens, as in the natural point for instance, every thing is most perfectly geometrical, so the same perfection continues even to the greatest ens; that is to say, throughout there is maintained a similarity. The infinite itself is the cause and origin of the finite world and universe: this infinite is a one in which there is no relation of greater or less, and in which all things that ever can be, are in simultaneous order. In our conceptions, what is infinitely great and what is infinitely small are, as it were, two separate things; but inasmuch as the infinite possesses the utmost perfection and similarity, it follows that such as it is in its greatest, such also it is in its least ens; nor can we conceive of any intermediate between greatest and least in the infinite. Our finite senses are apt to conceive, that, in the infinite, there is some finite intermediate between the least and the greatest, tending from the least to the greatest; but inasmuch as what is finite is as nothing in respect to what is infinite, we ought to consider the intermediate between them as also respectively nothing; so that in the infinite the greatest and least ens are one and the same; for a finite difference between two infinites implies no other state in the infinite than that of its being one and the same. Nature, the offspring of the infinite, derives also this property from it, that it is most perfectly similar to itself, for the reason that nothing imperfect or dissimilar can arise from the infinite. Since however nature is finite, it follows that in the state of perfection and similarity to herself to which we have adverted, she derives this peculiarity and this only at it were from herself, that she is susceptible of degrees and moments, of dimensions, modes, ends and boundaries, as also of variety in her state, which is not the case with the infinite.

With respect to the nature and series of finites we observe, that man is introduced into the world and its mechanical order, as an intermediate between its least and greatest things; for his senses perceive such things as are in general equidistant between the extremes of nature. The whole of what exists is not comprehended within the sphere of his observation: his wonder is excited as well by what he sees as by what he does not see; thus, whichever way he turns his eyes, he cannot but feel astonishment, one extreme of nature being above his senses the other being below them: he aspires however to a knowledge of both. Now inasmuch as nature maintains the highest similarity to herself both in her greatest and in her least entities, we may, from what we see and feel, arrive at a knowledge of what we neither see nor feel. Thus has nature designed that we should be instructed through the medium of the senses: in addition to which is imparted to us a soul, and to the soul a faculty of reasoning and analyzing, a faculty which may extend its operations even to the senses; so that, by help of reasoning and analysis, or of the ratios of the things we sensate, we may arrive at some knowledge of those we do not.

The magnet with the play of its forces we both see and we do not see; hence our wonder at the phenomena it presents. In the magnet and its sphere there is however a type and effigy of the heaven; a mundane system in miniature presented to our senses and brought within the limits of our comprehension.

In the sphere of the magnet are spiral gyrations or vorticles; in like manner in the sidereal heavens there are spiral gyrations and vortices. In every vorticle round the magnet there is an active centre; in every vortex in the heaven there is also an active centre. In every vorticle round the magnet the motion is quicker near the centre than it is at a distance from it; the same is the case in every vortex in the heaven. In every vorticle round the magnet the spiral gyration is of greater curvature in proportion to its nearness to the centre; the same is the case with every vortex in the heaven. In every vorticle round the magnet there are, in all probability, corpuscles fluent round the centre and revolving round an axis; such also is the case with every vortex in the heaven. The vorticles round the magnet mutually colligate themselves by means of their spiral motions, and, thus colligated, form a larger sphere; the same is the case in the sidereal heaven;—not to mention other points of agreement of which we shall speak in the sequel. All things are similar one to the other; because in small things as well as in large nature preserves the greatest similarity to herself; especially as the vorticles round the magnet possess particles and elements of the same nature as the vortices of the great heaven; and inasmuch as these vortices are similar, as well as their causes, therefore the effects produced are similar.

Now inasmuch as man is not created prone to the earth like beasts, but is endowed both with an upright mien in order to enable him to look upward to the heavens, and with a soul derived from the aura of a purer and better world, in virtue of which he is allied to heaven; let us avail ourselves of this privilege to exalt our thoughts to the regions above; and from a vile stone of the earth and its magnetic powers, contemplate what is similar on the largest scale, and learn the nature and laws of the material heavens both visible and invisible. Let the mind thus soar into the vast regions of the universe; and, as much as in it lies, while sojourning in a body confined to the earth, enjoy the wonders of the heavens above. Perhaps some one may observe—Supposing we do, what then? Shall we become the wiser?—Alas! we are but finite beings, and the objects we survey are themselves but finite. Our wisdom therefore will be but that of finite man; a wisdom derived from a knowledge of finite things, which must itself be consequently finite, and which therefore in relation to that which is infinite must be nothing. In this case, what remains for us to do? To let all our wisdom terminate in admiration of that Infinite Being who is the author of the finite universe; even as when our survey of a skilful piece of mechanism leads us into admiration of its maker.

1. *The elements both active and passive, as explained in the first part of our* Principia, *operate on a small scale in the same manner as on a large one; in a volume, in the same manner as in a system; in a vorticle round the magnet, as in a great vortex round the sun. They operate in the same manner whether the active centre be an insignificant effluvium continually moveable round its axis, or whether it be a large and continually moveable solar centre. In the heaven or finite universe there may be innumerable vortices of this kind, if there be innumerable active centres; or there may be as many vortices as there are suns or stars.* For these elements are the first, the most universal, the most simple, and are *(parum)* unmodified; hence they are fluent in a vorticle, in the same manner as in a vortex; in a volume, in the same manner as in a system; and round an effluvial particle in the same manner as round the sun. Since the element is the same and since the cause is the same and similar, it follows that the same motive force and the same nature prevail in the largest as in the least ens; and, as we have before observed, it is the same in the things above our senses as in those below them.

2. With regard to the motion of each vortex, it follows from the parallelism and similarity between the vortices of the magnet and those of the sidereal heaven, that *the motion of each vortex is from the active or solar centre to the circumferences; but that the motion towards the equators of the parts is not similar to the motion toward their poles, by reason of the geometrical difference in the figure of each part. In consequence of this difference of motion, the formation of the spiral gyrations is toward the poles and axes of the parts; that is to say, in the larger system, toward the poles of the zodiac. The spiral gyrations have a greater curvature in proportion to their proximity to the centre of motion or to the sun or star; from which the farther they are, the less is their curvature. The spiral motion which takes place according to the poles or axes of the parts, is expanded and unfolded*

into one more and more rectilinear, till at length it terminates in a common or rectilinear or parallel situation of the parts. These propositions being the same with those which I have stated in the First Chapter of Part II., when treating of the magnet, it will be unnecessary here to enter into further explanation.

3. It follows likewise, that *two solar or stellar vortices are more closely colligated by the spires nearer to the centre than by the more remote, as is evidently the case with the magnetic vorticles; that they may undergo colligation either at a great or at a small distance; that they may be reciprocally colligated if one axis be opposed to another, but not if one equator be opposed to another; that colligation as to the poles is direct, but that colligation of the poles with the equators of the parts is indirect and oblique; that there is no colligation as to the equators of the parts, that is to say, in the large vortex, as to the zodiac; that the centres of motion or the various suns and stars may thus be at greater or less distances from each other. If there be several in a smaller space or at a smaller distance, the gyration of one is not disturbed by that of the other.* To prove this would be only to repeat what we have before stated.

4. *That the active, solar or stellar spaces in the middle of the vortex are there in their own natural locality; that they cannot be removed out of the vortex; that the centre is indivisible and inseparable from the vortex, and the vortex from the centre; that one follows the other; and that there cannot be two or more suns, stars or active spaces, in one vortex.*

5. Further, that *one vortex with its active centre constitutes one heaven of itself or one mundane system; that several vortices with their centres form together a certain sphere; that a sphere consisting of many vortices of the same kind has its own proper figure, and the figure of every sphere its own proper axis; that the vortices inflect their course in every direction from one axis, and curve it toward another; that round this other axis they incurvate their course in like manner, whence by the colligation of the vortices the sphere passes on to another axis; that the sphere is so colligated with its axis, that all the vortices in the entire sphere have a reference to the axes, so that no vortex can be moved out of its place, unless the figure, connection, order, and course of the whole sphere be in some measure disturbed: that vortices are*

larger in proportion to their greater distance from the axis as also in the axis; that the whole visible sidereal heaven is one large sphere, and that its suns or stars together with their vortices, are parts of a sphere connected one with the other in the manner we have mentioned.

6. *That the axes of the vorticles in this sphere are variously inflected or incurvated, and that all the elementary particles in this sphere have the same situation as the vortices themselves, or the sphere itself; that hence the vortices, as well as all the elementary particles in the axes themselves, are spheres having a rectilinear disposition; but those extending from the axes a curvilinear disposition, or one which is inflected relatively to the axes.* We have before shewn, that the elementary particles are in the same site with the vorticles, or that the site of these particles is according to the figure of the sphere. For if there be a vortical motion among the elementary particles, and if one vortex be conjoined with another by means of its motion, then it is conjoined as to its spires; and inasmuch as the spires flow at first in a direction almost diametrical and afterwards in one more oblique to the axis of the parts, as represented in Fig. 1, (Part II., p. 216,) the parts also must necessarily be disposed into the same situation; that is to say, they will be adapted, together with their vortices, to the same situation. If there be a parallelism of the gyrating volumes, there must be a parallelism of the parts; such as is the conjunction of the vortices, such is that of the parts. The general motion and situation cannot be contrary to the motion and situation of the parts; for, according to our rule, the motion of the volume is the motion of the parts, and *vice versâ.* Thus the order of the one determines the order of the other. It is only by similarity of situation that equilibrium and colligation are obtained and preserved. Suppose a number of cylinders jumbled together, and one general motion be originated among them, every particular cylinder will at length accommodate itself to this motion: the situation of all, when in motion, will become concordant: one cannot lie in a direction transverse to the other, or be moved in a direction transverse to the motion of the other: the general motion tends to equilibrium by means of the situation and conformably to the figure of the parts. Further, if we communicate a motion to other and

similar cylinders, and reciprocally apply to each other or conjoin the two volumes of cylinders thus in motion, they will arrange themselves according to the mechanism of their motions; as will in like manner the parts of the volumes. The reciprocal application of the parts gives to the volume its perpetuity of motion. According to our thesis therefore it follows, that in a sphere of the same kind all the elementary particles arrange themselves into the same situation as the vortices, or into the same which is occupied by the sphere; that consequently the vortices, as also all the elementary particles in the axis of the sphere, lie in a rectilinear situation; but that from the axis they are bent into a curvilinear situation or one which is inflected in regard to the axis. Hence it follows, that *the elementary particles in the whole of this sphere or sidereal heaven, do not refer themselves to one and the same pole, except only in the axis of the sphere; that all the vortices or mundane systems which are in this axis possess the same poles, and that all the vortices or systems out of this axis do not possess the same poles, but that the poles are according to the situation of the systems in the sphere.*

7. *That there may thus be axes variously inflected, according to the application of the neighbouring or circumambient vortices. That if the axis of a vortex be inflected, the spiral gyrations according to the equators of the parts or zodiac of the vortex are not circular but elliptical. That the active centre cannot be in the middle of the vortex, but is in one of its foci. That if the axis be variously inflected, then at various distances from the centre there are various ellipses, or that there are various eccentricities relatively to the active centre. That the planets move elliptically in a vortex of this kind, the axis of which is variously inflected; and that their sun is not in the middle or centre of the vortex, but situated variously in one of the foci.* Of these principles we have already treated in Chap. I. of Part II. From what we have above said, it also follows, that the situation of the parts is according to the application of the vortices; or that in the axis the figure of the sphere is rectilinear; but round the axis, inflected. If now the situation of the parts be inflected, then the vortical or spiral motion terminates itself in a like situation; in this case not in a rectilinear but curvilinear situation, yet still in an ultimate parallelism of the parts. Let us now see what sort

of vortical motion takes place in a volume, when the axes of the parts do not lie in a right line. When they lie in a right line, then all the spiral motion towards the equators is circular; the centre itself is always in the middle, for the motion flows in a regular manner, inasmuch as it terminates in a rectilinear situation of the parts. When however they lie in a curvilinear direction, the motion extends itself indeed on every side immediately towards the equators of the parts, but in such a manner as to terminate in a parallel, and in this case a curvilinear situation of the parts; consequently the motion is not of a circular, but of an elliptical or other figure; nor can its centre be in the middle of the figure. The more *in*flected is the situation of the parts, the more does the gyration change from the circular into some other figure; the more does it on one side recede from the centre, and on the other approach to it. If we describe a curve winding inwardly on every side, and at any given points of the curve erect perpendiculars or diameters, and upon these describe circles, the diameters or circles will on one side of the curve approximate more closely to each other, while on the other side they will be more widely separated. At one extremity of a diameter drawn perpendicularly across the surface of the curve, the distance to the centre or point of inflection will be less than it is at the other extremity. In like manner if spiral circles be described perpendicularly or obliquely to the inflected axis, the distances from the centre will be different according to the different curvature of the axis: the greater the curvature of the axis, the greater will be the distance from the centre on one side than on the other; while on the other hand, the less the curvature, the less will be the difference of the distance to the centre on either side. The figure of gyration therefore depends upon the situation of the parts; the more eccentric the gyration, the more curvilinear the situation of the parts. The incurvation of the situation of the parts arises from the application of the neighbouring vortices. If the vortices be applied to each other, at their axes or equators, the more may the situation of the parts be inflected; the parts and also the gyrations are inflected at the same angle and distance in which the neighbouring vortices are applied; so that there exist different flexions of the parts and of the gyrations at different distances from the centre, consequently different ellipses and eccentricities. We shall explain in the sequel, how the planets, equilibrated and fluent in a vortex of this kind, follow the vortical current, and describe the same figure. We are to bear in mind that the axis of every vortex equals the whole width of the vortex, as we have shewn in Chap. I., Part II. Hence it follows, *that all the vortices which are directly in the axis of the sphere or sidereal heaven, are not inflected as to their axes; but that their gyrations are spirally circular, and that their centre is in the middle; but that round the axis, where they begin to circumflect themselves, their gyrations are elliptical, and that their active centre is in this case not in the middle; that hence there are different and numerous eccentricities. Consequently that our solar vortex is not in the axis of the sphere, but is near the axis where there is a considerable incurvation or inflection.*

8. *That the common axis of the sphere or sidereal heaven seems to be the galaxy, where we perceive the largest congeries of stars; that along the galaxy all the vortices are in a rectilinear situation and series, and cohere as to their poles; that, in like manner, they are there colligated more intimately, and with spires of greater curvature. That the other solar or stellar vortices afterwards proceed from the axis, and inflect themselves in different directions; but that nevertheless all have reference to that axis.* This is a consequence of the preceding observations. For the greater the number of active centres in the same space, the closer and more interior is the colligation of the spires. Their largest congeries is in the milky way, and there also is their reciprocal conjunction the strongest. Hence likewise the ancients feigned the existence here of the palace and hall of their deities. When the gods ascended into heaven, along this line lay their august route: here stretched the archway over which they crossed, and whence each diverged to his own particular habitation and kingdom. For here lies the chain and magnetic course of the whole of our sidereal heaven.

9. *That no change can occur in one vortex, which is not in some measure perceived in the adjacent, as also in all the rest as far as the axis extends, and hence throughout the entire sphere.* For the vortices are mutually connected like those round the magnet, and it is by reason of connexion that a sphere continues

to subsist. The vortices in connexion with each other are only parts; parts preserve the connexion: if one part be deficient, there is a corresponding deficiency in the connexion: if one link in a chain be removed, lengthened, or curtailed, all the links of the chain alter their position: if one link be moved from its place, the whole chain is moved with it; for taken collectively they form one contiguous body: all the parts taken together originate the contiguity. If you prick a nerve or artery in an animal, all the nerves and neighbouring arteries are immediately sensible of it. Hence, in consequence of the vortices being in series and connexion, no change can happen in one which is not perceived in the other. If the least part be deficient in a regular figure, there no longer remains the same ratio of resistance.

10. Hence it follows, that *from a given eccentricity and elliptical figure at different distances from the centre, the skilful geometrician may infer the situation of the neighbouring vortices, and the incurvations of the axis; while, on the other hand, from the given situation and distance of the neighbouring vortices, and the incurvations of the axes, or from the situation of the parts, he may infer what spiral gyration may exist at different distances. Thus from given ellipses or orbits of the planets, he may know the incurvations of the axis, as also the situation of the neighbouring vortices, together with various other particulars.*

11. *That there may be innumerable spheres or sidereal heavens in the finite universe; that these may be colligated one with the other, like the spheres of two magnets; and that the whole visible sidereal heaven is perhaps but a point in respect to the universe.* Few are the objects perchance comprehended within the range of our bodily vision: the greater number are to be comprehended only by the mind. The sidereal heaven, stupendous as it is, forms perhaps but a single sphere, of which our solar vortex constitutes only a part; inasmuch as this universe is finited only in the infinite. Possibly there may be innumerable other spheres, and innumerable other heavens similar to those we behold; so many indeed and so mighty, that our own may be respectively only a point; for all the heavens, however multitudinous, however vast, yet being but finite, and consequently having their bounds, do not amount to a point in comparison with the infinite. Consequently if all the spheres, if all the

heavenly hosts are not even a point in respect to the infinite; if the whole visible sidereal expanse, which to our eye appears so immense, be only as a point in relation to the finite universe; if our solar vortex form only a part of the sidereal expanse, and our own world only a small part of the solar vortex; truly may we ask, What is man? Can he be such a one as he feigns himself to be? Vain-glorious mortal, why so inflated with self-importance? Why deem all the rest of creation beneath thee? Diminutive worm! What makes thee so big, so puffed out with pride, when thou beholdest a creation so multitudinous—so stupendous around thee? Look downward upon thyself, thou puny manikin! behold and see how small a speck thou art in the system of heaven and earth; and in thy contemplations remember this, that if thou wouldest be great, thy greatness must consist in this—in learning to adore Him who is Himself the Greatest and the Infinite.

CHAPTER II.

ON THE DIVERSITIES OF WORLDS.

The universe and its laws, such as they are or may be, we have amply explained in our former chapters. We now proceed another step, and enquire whether nature can extend her bounds still further; for certain it is, that she is most profusely fertile and ever essaying at further ends, inasmuch as she is never at rest, but always desirous to advance and to extend the bounds of her dominion; nay, the more she does so, the greater is her luxuriance and the stronger her efforts to give birth to fresh productions. Her forces she extends in the infinite, in which are neither boundaries nor ends, and in which therefore without end she may continue to multiply. Yet multiply as she may her finite productions, nothing is hence subtracted from the infinite; nor can she arrogate to herself anything of the infinite; for the infinite is without end; proceed as far as she may, yet, in respect to the infinite, she is nothing; and after all she has acquired, there still remains the infinite unacquired. Be nature as vast as she may, she can never be adequate to one point in the infinite; nor, if I might so speak, ever occupy the extent belonging to this point. Hence may arise new heavens one after the other; in these heavens, new vortices and mundane systems; in these vortices and systems, new planets; around the planets, new satellites; and in this manner, at the will of the Deity, new creations may arise in endless succession. Hence how many myriads of heavens may there not be! how many myriads of mundane systems! And if in one heaven or celestial sphere there may be myriads of these, how countless must be the number of the planets with their satellites, especially in comparison with the number of heavens! Indeed the astronomer is lost in attempting the calculation. Now no one will deny, that these heavens and earths originate from certain causes, and that they take their rise in time and in successive order; nor is there anything to prevent us from conjecturing that at the will of the Deity may arise fresh systems at every moment; for there is nothing to shew that it is physically impossible. If now we admit, that new worlds may thus be originated, that they arise from the same causes as the others, and in the same manner; then are they subject to the same contingencies, and experience the same vicissitudes as those which appertain to our own planet. We may also conjecture, that each earth in its infancy would be similar to ours in its infancy; that in this infantile state, every living thing upon its surface would exhibit the bloom of youth, would wear an aspect full of smiles, and would disport itself as it were with the joys of its existence; that this infantile and genial character would manifest itself both in the mineral, vegetable, and animal kingdom; and thus that the golden age would extend its reign throughout every part of the universe, especially at the time when the sun himself would be only in his youth, and the earth he illumined, like our own in its earliest years, would be replete with every species of delight. In a word, we might say, that infant heavens and earths were successively coming into existence in proportion as the others declined in age, grew hoary with years, and fell into decay. From a mere possibility however we cannot reason to actuality; though when the mind indulges in conjecture, it cannot but lose itself in the regions of immensity. If, however, in these earths we could suppose the existence of an animal kingdom of the same kind as our own, then we must also suppose it subject to the same contingencies, changes, modes and series, through which it must pass to arrive at the same perfection; but since we cannot presume that, in these respects, all other worlds are absolutely similar to our own, so we cannot presume them to be tenanted by a precisely similar race of living creatures. Let us however proceed from conjectures to realities.

1. That *no world** *can exist, abounding in any variety of*

---

* *Mundus*, or mundane system.

objects and phenomena, without first passing through a succession of states and of intervals of time; through a succession of changes and contingencies; through modes or modifications; through series of things successive, simultaneous and coexisting; likewise through connexions of series; as also iterated separations and connexions; whence arises the perfection of its compositions. This we may conclude *à priori* and *à posteriori;* from first principles, and from phenomena. Nothing can come into existence without a mode; nothing can undergo a modification without a contingent: no contingent can exist without changes [*vices*], which must be assumed either before or at the moment of existence. There can be no vicissitude except among entities which are composite, and which preëxist; no entities can preëxist unless there be causes; no causes can produce and bring anything into act, except by means of contingents and changes: thus we return by a circle to the first simple, in the primitive force of which are latent all the entities which are afterwards developed. Variety is the perfection of the world. Were the elements of only one or two kinds, then could the other elements never have appeared; such as ether, air, fire, and others of various kinds. Were there no ether, there could be no light; no rays distinguished by degrees of shade; no beautiful variety of colors, such as is now presented to view; no visual organs to adapt themselves to the rays and receive them, or to communicate to the soul the pleasurable impressions themselves experience. Were there no air, there would be no undulation to set the tympanum of the ear in harmonic motion; no voice nor articulate sound; no melody nor harmony to soothe the senses and the soul; no breath for the lungs to draw; hence there would be no animal or animal kingdom; consequently no human being, except such a one as was devoid of every sense, and lower than the brute. Again, in regard to the mineral kingdom, without a series of things successively and simultaneously existing, it would be entirely empty, or provided only with the most simple furniture. There would not be such numerous kinds of salts, stones, and earths, argillaceous and much less metallic substances: there would be no relative values attached to substances, because no difference between them, nor any variety. The mineral kingdom is itself an effigy of the changes which take place at the formation of the earth; and of these, wherever the surface of the earth has been penetrated, we have abundant proofs; for descend as low as we may, even to the reputed regions of Tartarus and Pluto, we never find in the course of our passage any one thing absolutely similar to another; we are always meeting with something new, something different; and every new and different substance is only an indication of some different change. Look abroad on the vegetable kingdom; how varied is it! how pleasing, how delightful because of this variety! And why so varied, but in consequence of the variety prevailing in the mineral kingdom, which contains its origin, root, and essence? What enchanting variety salutes the eye? Every herb is furnished with an abundant supply of seed; every glebe around us gives birth to profusion of produce; few comparatively are the places undiversified by herbs or grasses, or flowers of some kind, exhilarating and regaling the senses both of sight and smell. If we traverse the various groves, woods, and forests, well may we with the poet exclaim, that all is there big with future birth. Similar is the case with the animal kingdom, which derives its origin from the three former; namely, from the elementary, without which no animal could draw any breath, neither the eye nor the ear could perceive, nor could any motion pass from the outward sense to the inward soul to announce any change occurring in the elements; in a word, without the elementary kingdom there would be no life. The animal kingdom derives its origin also from the vegetable, out of which it receives nourishment (on the vegetable kingdom itself vegetating); and again from the mineral kingdom, because it consists of parts derived from this kingdom. Hence it has its first beginnings from all these together, from which it finally introduces itself into the world. In these kingdoms the varieties are so great, that chemistry and the physical sciences labor as it were under the accumulation of the phenomena. Were however any part wanting, the world would cease to be so perfect; because some part would be deficient in the order of connexion; some link deficient in the chain. Hence the perfection of the world consists in its varieties; and inasmuch as variety cannot exist except by means of changes, it follows, that the world is brought progressively to its perfection by means of various changes, contingents, modifications, series of things, and their several connections. Hence likewise it follows, *that the world is rendered the more perfect in proportion to the greater number of changes and contingents which concur in its formation; and to the greater number of modifications and existences thence resulting of things successive, simultaneous and coexisting; as also in proportion as they are more connected, or as there is a longer series of them, and as the connexion of the series is more multiplicate.* For the more numerous the series, and the more various their connexions, the more numerous are the things which exist and which are capable of modification; the more numerous are the causes and effects of the varieties; the greater too is the scope for the exercise of mechanism and geometry, and for developing the motive forces of nature.

2. *That the world subsists by the same series by which it exists; and, in respect to its subsistence and existence, has perpetual relation to its first principle. That the more perfect the world exists and subsists, the more easily may it refer itself to its first principle; consequently the more perfect and beautiful is it in its direct series than in its indirect; in things composite and connected than in things simple and separate; in series possessing a larger and freer motion, than in those possessing one more restricted.* Connexion originates from parts existing in succession; for by reason of these parts it is, that the connexion subsists. If effects remain, so must causes: if causes are not continually associated to them, the effects cease. Thus effects themselves are latent in causes, and thus also the world has its subsistence in its first principles; thus, likewise, is each end perpetually in possession of its intermediates; and thus do the various worlds endure from one age to another. That to which the world has its principal relation, is, its first beginning; hence its first principles, both active and passive, are not only in perpetual connexion, but in perpetual vigor; provided all the entities in its series are in motion,—in the same, for instance, as that from which they derived their origin. Thus does nature always subsist in a state of life as it were, and behold her several origins in a state of connexion. In animals, as in elements, every series has subsistence only by motion; for the whole elementary particle with all its individual parts, and the individual parts of

these again, until we arrive at the original point, we perceive to be in a kind of perpetual motion; in each elementary particle we see remaining the whole process of its creation; resembling, as it does, the world, both as it exists and subsists; that is to say, in every particle nature may contemplate her first end and her intermediate destinations.

3. *That the changes and contingents may be infinite, as also the varieties of modifications; and hence that there may be infinite genera of entities simultaneously and successively compounded, and afterwards connected; consequently infinite series of these entities.* Suppose the world went through a thousand changes before arriving at its perfection; (that it actually passed through many a thousand will be demonstrated in the sequel;) now if, in one among these thousand changes, there existed even but a single variety, it would from this time progress to a kind of perfection different from what it otherwise would; for this variety would give rise to another series of things, different from the one otherwise existing. Hence were these thousand changes successively multiplied into each other, according to the rule of progression, even thus we should not arrive at the number of varieties produced, which would be so immense that volumes could not comprise them. Now we may likewise have an equally great variety of series; for were there the least diversity in any intermediate change, it would immediately give rise to another, collateral and perfectly different, series of things successively and simultaneously existing. Nor are the changes and contingencies alone liable to these varieties, but also their modifications, and the entities thence successively or simultaneously arising, or the parts constituting the world. Hence it follows, that *if the world consists of a series of parts and compositions simultaneously and successively arising, there may be as many series as there are worlds, or as many worlds as there are series; and thus, that no one world can be absolutely similar to another.* For no changes, contingents, modifications, or entities, capable of modification, can be assigned as absolutely similar one to the other.

4. That *nevertheless, in every mundane system, the principles of geometry continue to be similar; as also nature and mechanism,*

as to first principles and motive forces; and that the diversity consists only in the diversity of the series, in respect to degrees, ratios, and figures. For figure and space belong to every entity as an attribute; and hence geometry accompanies these entities throughout every mundane system; so also does nature and mechanism, inasmuch as its motive forces cannot be separated from geometry. There are however degrees, ratios, and figures, which are various according to contingents, vicissitudes, modifications, and their series; and which, therefore, may be as numerous as these are.

Nature, consequently, cannot be modified in one world in the same way in which she is in another; nor are the entities in one world capable of being modified in the same manner with those of another. Mechanism presents itself under different conditions; because ratios, moments, and degrees are different: all objects have a different configuration, and thus analysis exhausts all its proportions. In other worlds the air and ether, if there be anything similar to them, do not experience the like tremulations; the organs of sight and hearing are also affected by them in a different manner; nor perhaps are our organs capable of receiving the undulations of their elements, because they are not constituted in accordance with their mechanism and motions. The animals of this world might there, perhaps, be deprived of the use of their senses. Machines of every kind might there, perhaps, be constructed by different rules and by a different application of mechanical powers. The magniloquent Archimedes, who talked of moving by his mechanism the world out of its place, were he translated to another system and earth, might perhaps somewhat lower his tone, when he found in those worlds all his skill and ingenuity disappear, and himself at a loss how to apply the common powers of mechanism; for, if he there wished to make any experiments, he would have first to learn the very first principles and rudiments of mechanism; which could be deduced only from the phenomena peculiar to that earth. There would the various motions of nature tend to their equilibrium by proportions and figures very different from such as we find on our globe; there should we find other modes, and other contingents and causes, concurring to the production of phenomena; for there would be no phenomena absolutely similar to ours; compared with ours, they might indeed appear to be prodigies. The learned of those worlds, therefore, might excite only a smile from the learned of ours; until the latter had first been initiated into a knowledge of the causes of the phenomena there presented.

From these observations we may be led to conceive, how great is the extent of our ignorance. Every one measures the degree of his wisdom by his knowledge of those things which have fallen within his own sphere. The limit of his own information he considers to be the limit of all that is attainable; for of what lies beyond his own sphere, he has no idea. The bounds of his knowledge are the bounds of his wisdom; and since he can advance no farther, he is apt to imagine that he knows all that can be known; whence he becomes elated with the notion of his possessing the highest attainable wisdom. The extent of his ignorance he knows not, because here all is dark before him; and in darkness there are no visible limits to enable him to measure extent. Could he, however, compare that which he knows with that which he does not know, how contracted would appear his knowledge, how oblivious of himself would he be! with eyes fixed upon the ground, how mute with astonishment would he stand, while exploring the unknown immensity before him! Despising his own attainments, how would he only smile at the pride of himself and his entire race! There is not a particle in our globe, with the thousandth part of whose nature we are acquainted. What do we know of the elementary kingdom, except a very scanty number of effects? In the mineral, vegetable, and animal kingdom, what we know is nothing to what we have yet to learn; for of that of which our senses are unconscious, the soul also is ignorant. And if such be the case with regard to this world, what is it not with regard to other worlds whose numbers are inconceivable! more particularly when we reflect, that the Infinite is capable of varying the primitive force in a simple in infinite ways; consequently, the powers of geometry and mechanism also in infinite ways; that He can give birth to nature not only after the manner in which it is presented to our view in this world, but in ways infinitely diversified; that He consequently can call into being an infinite variety of earths and heavens. In this therefore consists our highest wisdom, that we know how small is the extent of our knowledge.

CHAPTER III.

THE PHILOSOPHICAL ARGUMENT RESUMED CONCERNING THE FOURTH FINITE, AND ITS ORIGIN FROM THE SECOND ELEMENTARY PARTICLE.

Here we resume the subject of the finite, and take into consideration the one which is fourth in order; and which becomes one part in the series before the world finally arrives at its perfection. In elementaries there occur only the most perfect simples, namely, the passive and the active; from which, as from two principles, results a third or the elementary. Beside the finite, nothing active and elementary can exist throughout the whole of that kingdom: nothing, I mean, besides those two principles and a third compounded of the two. Nature is thus most perfectly simple, and indeed more simple still; since these three may be reduced to one finite; in which both principles are latent, the passive as well as the active; for the finite may be passive as well as active; since, according to our principles, in this entity is latent the cause of each. Whatever, therefore, we can predicate of the elements, is latent in one or every individual; in the finite, that which is similar in its part; and in its part, that which is similar in its point; and inasmuch as the quality itself of each principle is there latent, it follows that there is also latent the quality of producing things elementated, in an infinite variety of ways by different series. And inasmuch as the visible world is so diversified in all its kingdoms, and consists in a series of parts successively and simultaneously arising, the world cannot end in that in which it begins; or in any intermediate series; or in any first or following part; for, in this case, there would be no series, no ends, because no intermediates; consequently there would be no mundane system. Our first principles must therefore continue their chain of connexion down to the lowest and last things of our earth, or to the composites in which it has its subsistence.

With regard, therefore, to this fourth finite, we observe, that it is similar to the third; that the third is similar to the second; the second, to the first; the first, to its simple or point; and consequently that the fourth is similar to all the finites and to the point. That hence it is put into motion in a similar manner: it can be similarly passive, and constitute the surface of any particle: and can also be similarly active. That its attributes, essentials, and modes, are similar to those of the third finite; that it differs from it only in dimension, and consequently in degrees and moments. That its origin is similar to that of the preceding finite, for it arises from the second elementary particle in the same manner as the third from the first elementary particle. That the cause and place of its origin are the same; or that it is near the solar active space, where the second elementary particles were capable of being compressed into finites. To dwell any longer on this part of the subject would be useless, as in our remarks on the third finite, Part I., Chap. VIII., and in the other Chapters IV. III. and II., we have anticipated all that can be said on the qualities of the fourth finite; the only difference between the fourth and the others, being the difference between greater and less. We may thus see that it derives its origin from the second elementary particle, in the same manner as the third finite from the first elementary particle; consequently, that they are of a different dimension; that the fourth finite consists of individuals which are third finites; and thus that the third finite is raised to a higher power. We now proceed to shew that the whole solar and planetary chaos consisted originally of these fourth finites.

CHAPTER IV.

OF THE UNIVERSAL SOLAR AND PLANETARY CHAOS, AND ITS SEPARATION INTO PLANETS AND SATELLITES.

As yet the vortex is void and empty; running round the sun like a torrent, and ever pursuing the same gyrations. It encloses the sun in its middle, and never allows it to move out of its place or centre: on the other hand, neither does the sun allow the circumfluous element to penetrate into its own active space. It is this element which sets limits to the solar space; which enables us, also, to give it a name, and to call it a space; without this circumfluous element, we could not attribute locality to the actives, which would then dissipate themselves far and wide into an unfathomable void; thus transgressing their proper boundaries. On the other hand, the sun communicates to the element a perpetually circulating motion; enables us to impart to it the name of a vortex and a mundane system—a system which is only one among others forming the celestial sphere, and which, as a part of the sidereal heavens, contributes to the formation of the whole. The sun, therefore, is now in possession of its vortex, and the vortex of its sun; both together constituting a system; for one without the other cannot subsist. Hitherto, however, the sun is seen enthroned, though in a stupendous, yet an empty hall. Although his empire stretches far and wide, it is unpeopled by earths; he has no subjects to whom he can give laws, and who in return can serve and obey him. Moreover, the vortex itself is inane; possessing nothing which it may perennially carry round the sun; no earth to which it can impart its own revolutions.

Phœbus reigns aloft in a bright, sublime, but solitary abode. There are no hours, days, or years, as yet surrounding his throne and awaiting his will. As yet he is no charioteer, there being no chariot into which he may mount—no discriminated quarter to which he may direct his steeds; there is neither rising nor setting, neither east nor west; because as yet there is no earth to originate the distinctions of morning and evening; much less is there anything for the genial rays of the sun to warm, cherish, vegetate, animate, and vivify. Inasmuch, however, as the existence of the simple must precede that of the compound, the vortex, with its space which is the most simple, must exist antecedently to any earth proceeding from successively and simultaneously originating series; for the vortex cannot as yet carry within it any composite, since the composite itself has yet to be compounded; it cannot waft along its current any earth or planets; because these are not yet come into being, but have to be produced by changes, contingents, and modes of indefinite kinds. As yet the planets are only in a state of conception; the ovum only is produced, out of which they remain to be excluded.

Now reason dictates, that causes must exist before effects; the simple before the compound; principles before principiates; that is to say, actives, passives, and elementaries, before a series of things successively and simultaneously arising: the first must exist before the intermediate; the intermediate before the ultimate. Reason, therefore, dictates that the planets must derive their origin from causes, in time and in place; that causes are to be found in first principles; in fine, that the earths in our system must have had an origin by succession. Now if, according to reason, the planets have their origins in causes and in time and in place, it remains to be ascertained what those causes are; what the time, and what the place. With respect to causes we may observe, that they are no other than those which are latent in the first principles; that is to say, in the active, the passive, and the elementary which is compounded of both. With respect to time, the planets could have no origin before the existence of causes to produce them; that is, before the existence of actives, passives, and elementaries; with respect to place, their origin could be nowhere else but in the place in which their causes concurred to produce them; which could be only about the active solar space, where everything is present which could compound and give birth to such effects. And, inasmuch as causes always accompany the effects, it follows, that effects can be produced only in the place where the causes are. As yet all that pertains to the system is near the sun; and therefore, that the planets had their origin near the sun, will be the subject of demonstration in the present chapter. This may in some measure be concluded by arguments drawn *à priori;* as for instance, that the sun is the first moving power in its universe; that it is the parent of its own vortex; that to the sun everything in the vortex owes its origin, and also its subsistence; and, consequently, that the various parts in the vortex are its offspring. Now nature, in her gravid state, can give birth to her offspring only in the one place in which she abounds in first principles. She cannot be in her pregnancy, or labor in the midst of the vortex, or here give birth to her progeny; for the causes of conception and pregnancy do not lie at such varied distances from the sun; nor are they to be found among mere elementary particles.

To this conclusion reason herself may come by the aid of her powers of analysis. Hence merely from the light of reason, the ancient philosophers held that there was a certain universal chaos both of the sun and planets, in which were comprehended simultaneously all things which could conduce to the perfection of our system; thus, that both Tartarus and the sun, the day and the night, soft bodies and hard, lay primordially buried together; in fine, all the seeds and elements of the things subsequently produced; and if this universal chaos were in the vortex, it follows, that it could be only near the sun. Let us advert to these opinions of the ancient philosophers, before we proceed to the immediate subject of our chapter. All, with the exception of Aristotle, seem to have favoured the conjecture, that, primevally, the system we inhabit was only a rude, uncompounded, undigested mass; the parts of which were as yet undiscriminated; that from this mass all things afterwards sprang, as an infant from the womb. From this mode of conception they afterwards deduced the birth of the various orders of things; they imagined a state of conflict among these elements, not unlike the one arising from fermentation (for they knew that it was only by a species of collision that nature tended to a state of equilibrium); that, on the cessation of the discord, heavy bodies passed to their place, and light bodies to theirs; bodies without motion and bodies with motion sought respectively their proper situation; and hence, from reason guided only by a very few phenomena, they concluded that when the strife of nature was over, an harmonious world arose out of the chaos. These philosophers, therefore, were shrewd enough to guess the preëxistence of a chaos; although they were ignorant of the series by which the various things were brought into existence. The philosopher naturally embraces the opinion which seems to him to be the most agreeable to reason, the most resembling visible nature, and which presents the least difficulties; for he is anxious, of course, that in future ages his system should not fall to pieces, in consequence of inherent contrarieties. The mind, therefore, naturally chooses the least difficult path, which it pursues like a traveller in the dark, who gropes his way in the direction in which he meets with fewest obstacles; and so follows the path without seeing it; he touches the various objects that come in his way, although he knows nothing of what he is touching, and arrives at the end of his journey, though he cannot tell how. In the same way were the ancient philosophers led to presume the existence of a chaos common to the sun and the planets; although in what manner it existed, of what kind it was, and by what means it came to be such, they were altogether ignorant. This at least we may conclude from the ancient philosophy (a conclusion highly agreeable to reason), that primevally there was a universal chaos both of the sun and planets; while on the other hand, any other hypothesis is attended with no inconsiderable difficulties. Epicurus maintained, that the whole universe arose from a chaos; not only the earth, but the planets, sun, and all the stars; that is to say, the whole system of nature. Hence Aristophanes observes:

> Chaos and night
> Black Erebus, and squalid Tartarus,
> Were first of all; earth, air, nor heaven was yet.
> But in unmeasured gulphs of Erebus

The black-winged Night first lays a windy egg,
Whence in the circling hours sprang wished-for LOVE,
The golden feathers glitt'ring on his back,
Resembling the tempestuous vortices ;
He through the wild domain of Tartarus
Mingled with chaos' darkly winged form,
Begot our race and brought us forth to light.
Th' immortal kind, ere LOVE confounded all things,
Had no existence yet ; but soon as they
Were mingled, heaven with ocean rose, and earth
And all the gods' imperishable race.

The Comedies of Aristophanes.
Translated by C. A. Wheelwright, M.A.,
formerly of Trinity Col., Cambridge, 1837.

Moreover Ovid, borrowing his ideas from the ancient philosophers and Greek poets, thus beautifully and luxuriantly writes in his Metamorphoses :—

Before the seas, and this terrestrial ball,
And heaven's high canopy that covers all,
One was the face of nature ; if a face ;
Rather a rude and undigested mass :
A lifeless lump, unfashioned and unframed,
Of jarring seeds ; and justly *Chaos* named.
No sun was lighted up, the world to view ;
No moon did yet her blunted horns renew :
Nor yet was earth suspended in the sky ;
Nor, poised, did on her own foundations lie :
Nor seas about the shores their arms had thrown ;
But earth, and air, and water were in one.
Thus air was void of light, and earth unstable,
And waters' dark abyss unnavigable.
No certain form on any was impressed,
All was confused and each disturbed the rest ;
For hot and cold were in one body fixed ;
And soft with hard, and light with heavy mixed.
But God, or Nature, while they thus contend,
To these intestine discords put an end ;
Then earth from air, and seas from earth were driven,
And grosser air sunk from ethereal heaven.
Thus disembroiled, they take their proper place ;
The next of kin contiguously embrace :
And foes are sundered by a larger space.
The force of fire ascended first on high,
And took its dwelling in the vaulted sky ;
Then air succeeds, in likeness next to fire ;
Whose atoms from unactive earth retire.

Earth sinks beneath, and draws a numerous throng
Of pond'rous, thick, unwieldy seeds along.
About her coasts unruly waters roar;
And rising on a ridge, insult the shore.
Thus when the God, whatever God was he,
Had formed the whole and made the parts agree,
That no unequal portion might be found,
He moulded earth into a spacious round; &c. &c.

Book i. Translated by John Dryden.

It was the general opinion of the ancient philosophers, that Night and Tartarus originated from chaos; that from Night sprang the Earth, the Ocean, the Heaven or the Ether; in like manner also Love; so that Night and Tartarus were first-born and twins; that from these arose everything else of which the world consists. The ancients held also that, from the same chaos, the gods and goddesses derived their origin; hence they conceived that their origin was not from eternity, but in time, and cöeval with that of the earth; more particularly as some god or other presided over each element, and, indeed, over everything of which they had any general conception. The God who separated the various things out of the chaotic mass, they denominated Love. Ovid however intimates, that, as to himself, he was ignorant which of the gods it was that performed this office; for he observes:

But God, or Nature, while they thus contend,
To these intestine discords put an end.

And again:

Thus when the God, whatever God was he,
Had formed the whole and made the parts agree.
That no unequal portion might be found,
He moulded earth into a spacious round; &c. &c.

Aristophanes likewise observes:

Th' immortal kind, ere LOVE *confounded all things,*
Had no existence yet; but soon as they
Were mingled, heaven with ocean rose, and earth
And all the gods' imperishable race.

The Mosaic philosophy would seem to coincide with the ancient philosophy of the Egyptians, and also with this of the Greeks and Romans; for Moses likewise confirms the fact of the existence of a chaos, since he relates that *the earth was* *without form and void, and darkness was upon the face of the deep; and the Spirit of God moved upon the face of the waters;* so that, we see, he makes mention of a chaos, darkness, an abyss, as also of a Spirit. Hence some have been of opinion, that the chaos of Moses was the same with the chaos of the ancients; that the darkness he mentions was the same with their night, which arose from chaos; that his abyss was the same with the Tartarus or ocean of the ancients; that the *Spirit of God which moved upon the face of the waters* was the same with the Intelligence and Love which they imagined to be employed upon this occasion. Moses, having narrated the origin of the earth from chaos, first begins with light; and afterwards proceeds to the location of the greater and lesser luminaries in the heavens, such as the sun, moon, and stars. Having stated these circumstances, he declares that, *thus the heavens and the earth were finished, and all the host of them.* He likewise alludes to certain gods and sons of gods who disported with the daughters of men; as also to other details, resemblances to which we find in the ancient philosophy. In the eighth chapter of Proverbs, Wisdom is represented as saying, *When he prepared the heavens I was there; when he set a compass upon the face of the depth,* &c., alluding apparently to the deep mentioned by Moses; not to mention other particulars stated by various authors, ancient and modern, who have written upon this subject.

Let us, however, now observe how reason and the mutual connexion of our principles lead us to conclude, that originally there was a universal chaos, or a chaos common to the sun and planets; in which were latent the origins of all things; and which, by various changes, contingents, and infinite modes, ultimately produced series as long and multiplicate as we now perceive those of the earth to be; that is to say, series which filled and adorned this terraqueous globe with elements and minerals of the most diversified natures, as also with trees and living creatures. Let us first observe the origin of the earth; how it was conceived; how it lay *in ovo;* how, in this state, it was cherished, then excluded from the egg; and thus introduced into a state of infantine existence; how it gradually advanced to adolescence, and finally arrived at a state of old age. We observe, then:—

1. *That, by reason of the same causes, the second elementary particles are most highly compressed near the solar active space; that, in consequence of this compression, they cease to be elementaries; that finites exist in the same manner as first elementaries; but that these finites exist from second elementaries of a higher dimension, and are the fourth in order, the former being third in order.* From what we have said it follows, that the second elementaries are extremely similar to the first; that they are in the same volume with them, in the same gyre round the sun, in one and the same common state, and thus that each genus may fulfil the same destiny. It results also from the theory of each element and of the third and fourth finite, that, in the state of the formation of the vortex or before the elementaries can become circumfluent, they dispose themselves into a general and concordant motion, adapt either themselves to motion or motion to their figure, and are fluent in a state of equilibrium; that they may, in this state, be compressed; when compressed, may recede into themselves, and lose their elasticity and yieldance, that is to say, all their elementary character; that they may lose, in fine, one first principle of their nature, which is the active; thus that they cease to be elementaries, and exist as fourth finites near the sun. See Chap. VI., art. 21, 22, 26; Chap. VIII., art. 4; Chap. IX., art. 10; Chap. X., art. 3; also Part III., Chap. III.

2. *Although all finites possess this power of actuating themselves, that, nevertheless, these which have their origin near the sun are not capable of becoming actives, of introducing themselves into the solar space to its actives, in consequence of a difference as to velocity, circles, and mass; but that the actives which may have been casually made, cease to be actives, and necessarily remain mere passives round the solar space of the actives; that, consequently, the functions they there perform are those of a guard, to prevent the other finites of the same genus from penetrating into the solar space, and thus from any longer projecting themselves into it.* We have frequently stated in the former Parts of our work, that all finites may become actives, if they have free space allowed them; and in Chap. IX. of the present Part we shall explain how all these finites may become actives, like others of the same genus. In Part I.,

Chap. VII., sec. 2, on the Actives of the Third Finite, art. 6, 7, 8, we may see, that the actives of a higher power and dimension cannot be in the same space with the actives of the first and second, in consequence of the difference in velocity, circles, and mass, but must immediately, by means of the influx of the smaller actives, namely, the first and second, be immediately divested of all their active force. The consequence is, that these finites, deprived of all power of actuating themselves, occupy their place round the sun as mere passives; that, conglomerated round this space, they enclose it on every side; but that if they enclose they protect it, and prevent other finites of the same genus, which are present, from rushing in; for they operate as a fence between this space and the volume of similar finites; that is to say, they are intermediates between this space and the other finites.

3. *That in this manner the number and quantity of finites of the fourth kind more and more increase, by reason of the successive compression of the elementaries; and also condense themselves round the solar space. That the finites thus concrete into an immense volume, and crowd around and enclose the sun in such a manner as to form an incrustation; nor do they cease to act till the vortex be fully formed.* It is from the same cause as the former that these effects arise. For if in the process of the formation of the vortex the elementaries be compressed, and in consequence of their extreme compression cease to be elementaries, divest themselves of their elasticity and yieldance, and are deprived of their active principle, their number will continue to increase until the vortex be completely formed; according to the theory propounded in Part I., Chap. X. In this manner will the finites be drawn hither in crowds, and press closely upon the active space, and, like an extremely dense crust or cloud, will interpose themselves between the vortex which has to be formed and the solar space; thus also will they intercept the immediate force of the space, and its operation upon their vortex; they will destroy all contiguity; and consequently will throw into shadow the whole of the mundane system, darkening it as by an extremely opake cloud, and superinducing upon it another and different state. Thus also will they originate another remarkable vicissitude, by means of which will arise

new accidents, and as it were new causes, which will operate in giving rise to a further perfection of the world. In the sequel it will be shewn, that the sun, surrounded with this crust and shut up in the middle of it, is thus, as it were, in a gravid state, and big with a new production awaiting its launch into the vortex; and that in this manner it is, that not only the sun, but also all its planets, were once in a chaotic state; in which were latent the initiaments of all that was afterwards produced.

4. *That nevertheless this crust, consisting of fourth finites, which is formed around the sun, is rotated in a certain gyre; that it is thus representative, as it were, of an active centre in forming and perfecting the vortex, around which, consequently, the elementaries can nevertheless flow in a vortical current, but with a potency and force different from that which they would possess in case the solar space acted nakedly and contiguously upon the circumfluent elementaries.* That this congeries and crustaceous compages, consisting of fourth finites and surrounding the sun, has nevertheless a circulatory motion, is evident from this, that it is formed in this very motion itself. When the elementary particles cease to be elementary, the cessation is in consequence of the motion of the particles in contiguity, and is thus effected in motion. Hence, in every degree of compression, they retain and preserve the impressed force. By the compression of the elementaries upon the finites, no other state is induced upon them than the one which existed during the state of compression; the actives within constantly acting in the space, and an immense volume of elementaries without being put into a vortical motion, just the same as we see in our own visible world. When, for instance, a volume of water is carried round a centre or axis, we find that when the impulsory motion is stopped, the motion at first impressed nevertheless continues; until, in consequence of the mutual contact and renitency of the parts, a state of quiescence begins to be superinduced. Hence in the crust also which surrounds the sun, the pristine state of motion is for a considerable time preserved, and is changed only in consequence of an increase in its quantity, and after a certain interval; it may moreover be rendered less compliant, by reason of a condensation and multiplication of the parts, and by reason also of a lapse of time. For the parts tend to a state of equili-

brium; and inasmuch as they are not elementary, they in course of time gradually tend to a state of rest. In the meanwhile, as the forementioned crust is continuing its motion round the sun, it is not unlike the effluvium circulating round a magnet; which, by means of its motion round an axis, constitutes an active centre; so that all the elementary particles can move around the crust as a centre, and the vortex itself be advanced to another stage of formation. On this subject the reader is referred to the whole of the Second Part of our *Principia.*

The following is the substance of all that we have here to state on the subject of the figure and motion, or geometry and mechanism, of the solar crust. *The whole of this immense crust, together with the enclosed solar space, is not unlike an elementary particle; for in each elementary particle there is an active space, exteriorly to which flow the finites. Thus, both as to figure and motion, this chaos is, on an immense scale, an effigy of each individual part of an elementary particle. Thus is nature similar to herself in her largest as well as her least productions; and thus does she appear in her most stupendous proportions, as well as in her most minute.* In the present case, therefore, we may apply many of the remarks which we have formerly made on the subject of elementaries in Chapters VI. and IX., Part I.

5. *That this crustaceous matter, being endowed with a continual gyratory motion round the sun, in the course of time removes itself farther and farther from the active space; and, in so removing itself, occupies a larger circle of space, and consequently becomes gradually attenuated, till it can no longer contiguously cohere, but bursts in some part or other.* That this crust, covering and rotating round the sun, is removed gradually to a greater distance from it, is evident from this circumstance; that the space within is continually active, and incessantly acts upon the walls and barriers of its prison; that the crustaceous expanse or volume which is perpetually circumfluent, tends, by its centrifugal force, to a farther distance; like all other bodies having in any medium a circulatory motion, the rules and principles of which are sufficiently well known to the learned. It is evident, also, that the heavy bodies in the

solar vortex tend from the centre to the circumferences; on which subject we shall speak more at large in the sequel. The effort and tendency of this crust toward the peripheries of the sun and beyond them, arise, therefore, from a threefold cause. Now if the tendency of the crust is to fly off to a greater distance, it follows that it must become gradually attenuated, because the same volume occupies a larger circle. That the expanse becomes attenuated in consequence of forming a larger circle, is a purely geometrical fact; as also, that if it becomes attenuated and be in perpetual motion, it in some part or other becomes disrupted. It is needless therefore to dwell any longer on what is already demonstrated, and of the truth of which there cannot be a doubt. We shall only add, that this chaos, being on a larger scale similar to the most minute elementary particle, may, by too great an expansion, become disrupted, on the principle we have already mentioned in regard to elementary particles, Part I., Chap. VI., art. 27.

6. *That the solar crust, being somewhere disrupted on the admission of the vortical volume, collapses upon itself; and this toward the zodiacal circle of the vortex, or conformably to the situation and motion of the elementary particles; so that it surrounds the sun like a belt or broad circle: that this belt, which is formed by the collapse of the crustaceous expanse, gyrates in a similar manner; removes itself to a farther distance; and by its removal becomes attenuated till it bursts, and forms into larger and smaller globes; that is to say, forms planets and satellites of various dimensions, but of a spherical figure.* That the crust, when disrupted and collapsed upon itself, is disposed around the sun in the form of a zone, and in accordance with the equinoctial plane of its vortex, which is the same with the plane of our zodiac, is evident from the mechanism of the elementary particles, which, by reason of their situation and motion, form a vortex or gyration proceeding from the centre toward the equators of the parts; conformably to the direction of the spiral motion. This appears to be more particularly the case when we consider, that the element can now act on all sides and dispose the fluent parts into a conformity to the situation and motion of its particles; a circumstance which we may see illustrated by innumerable phenomena occurring in liquids. From our preced-

ing theory it is evident, that the zone, thus formed, has in like manner a rotatory motion, and becomes ruptured by its removal to a further distance from the sun. That it forms itself into globes, may be inferred from the equal pressure of the element in all directions. See Chap. VI., art. 46—49, Part I. It is in consequence of equal circumpressure, that liquid bodies glomerate into globes, as water does in air; quicksilver in water, air, and ether: indeed all bodies, when dissolved and liquefied by heat, and surrounded by an equable pressure of any element upon all parts, form themselves into spheres.

7. *That this crustaceous expanse may subside partly into itself, and thus consist merely of a volume of finites: that it may partly subside inwardly, or toward the solar space, and thus revolve itself round some active space; that it may partly subside exteriorly or toward the vortex, and thus enclose a volume of elementary particles. Thus that there may exist bodies of three different kinds, namely, planets, satellites, and erratic bodies straying round the sun, such as we are accustomed to denominate solar spots.* Of this subject however we shall derive a better conception from the figures about to be presented.

Hence it follows, *that these bodies, separated into globes, consist of fourth finites; that they direct their course into the vortical current according to their magnitude and weight; that they continue more and more to elongate their distance from the sun, until they arrive at their destined periphery or orbit in the solar vortex, where they are in equilibrium with the volume of the vortex.* On this subject see the sequel, Chap. X. and XI. Let us now illustrate by figure the nature of the chaos or crustaceous expanse and zone; for a thousand words will not convey the idea which may be derived from a single representation; and besides, the intellect may form a more distinct idea of an object in proportion to the more clear and distinct impression made by it upon the organs of the senses; so that we shall now have recourse to figures to delineate this chaos or solar crust, and its state of separation. Fig. 98. A is the solar space;

Fig. 98.*

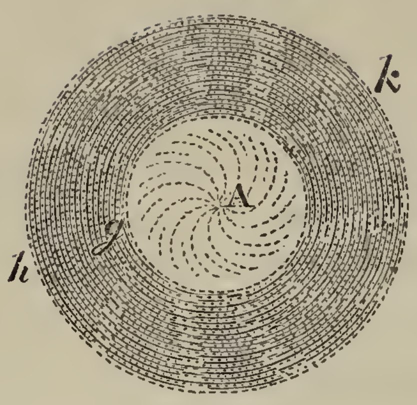
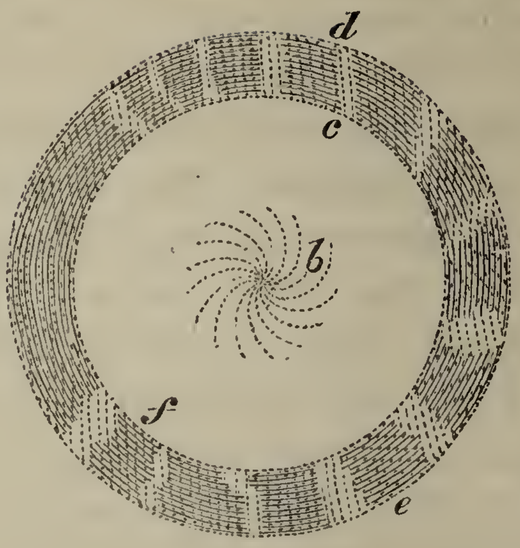


Fig. 99.*



kh the crust consisting of fourth finites, which revolves round the sun. Fig. 99 exhibits the same crust expanded into a larger ring, namely, *c, d, e, f,* whose volume equals in quantity the volume in Fig. 98. The whole internal space is occupied by the actives of the sun. Fig. 100 exhibits the same crust still larger and more expanded, broken likewise at *mn:* in consequence of which hiatus a passage is afforded to the vortical element for rushing in, so as to enable it to act upon all sides, as we shall more clearly perceive in the following figures.

Fig. 100.†

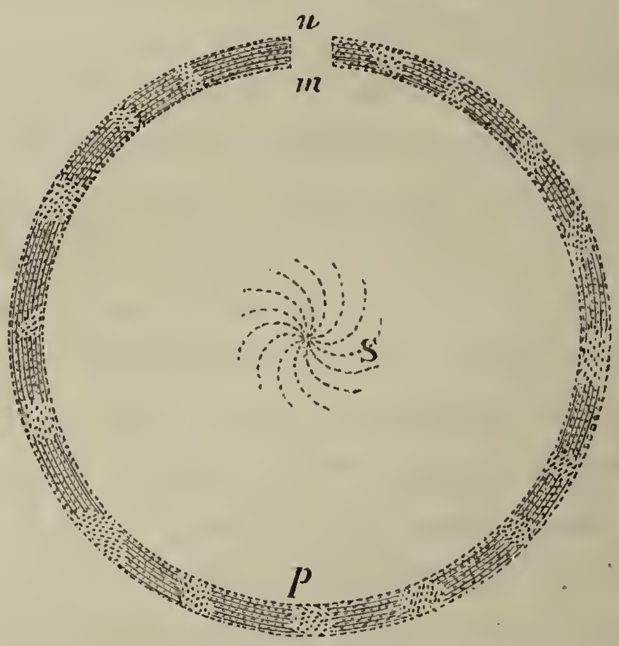


Fig. 101 represents the crust as having a still greater density, and about to undergo a disruption. Fig. 102 represents the

---

* In the original, plate XXV., figs. 2 and 3.

† In the original, plate XXV., fig. 4.

Fig. 101.*

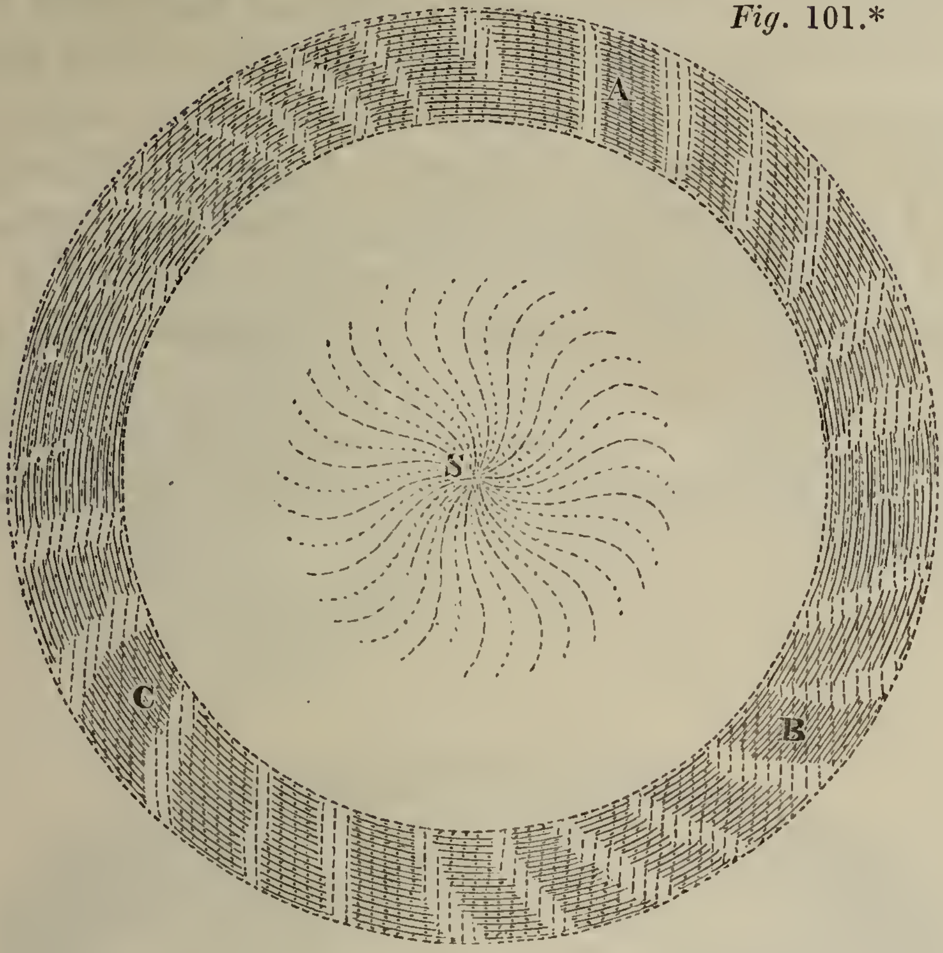
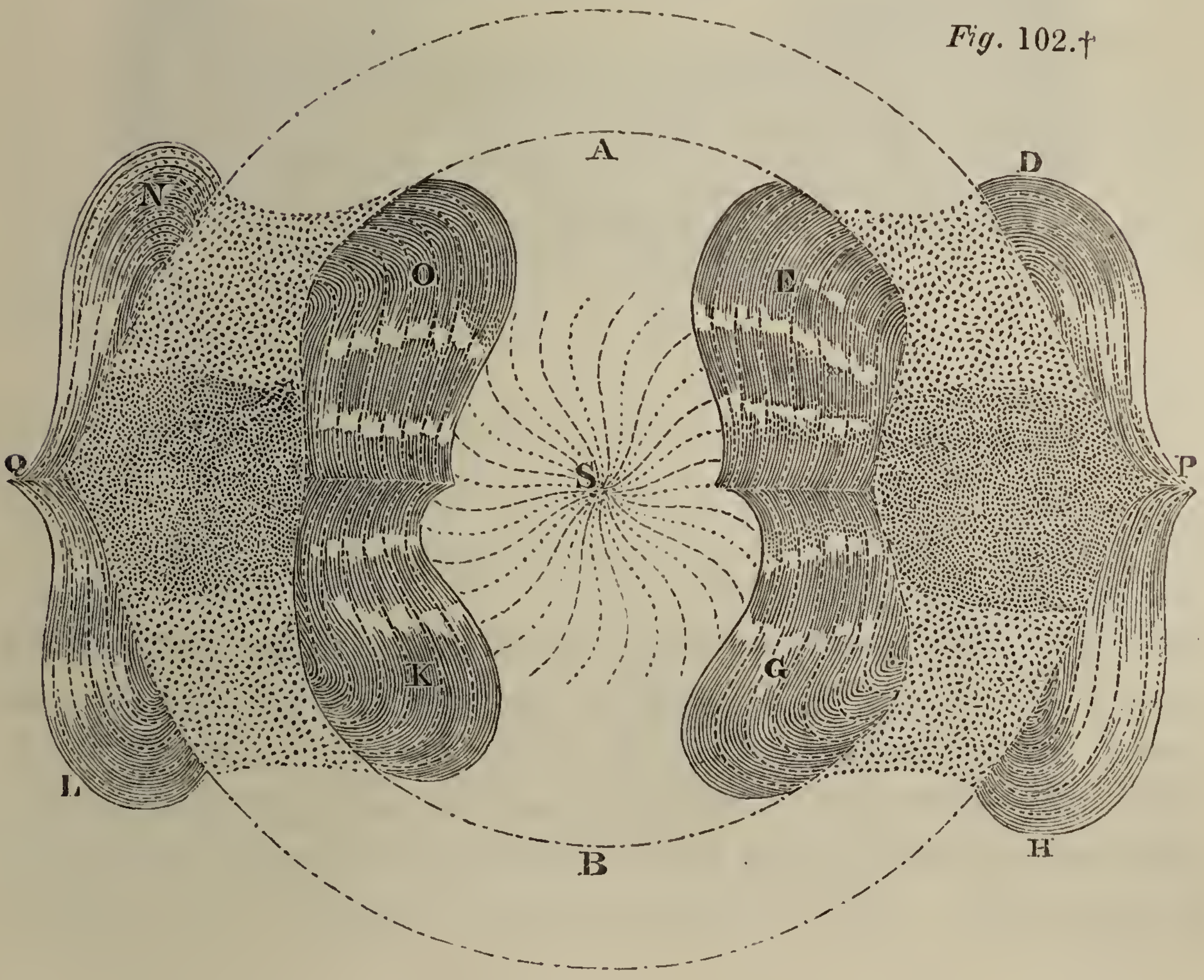


Fig. 102.†

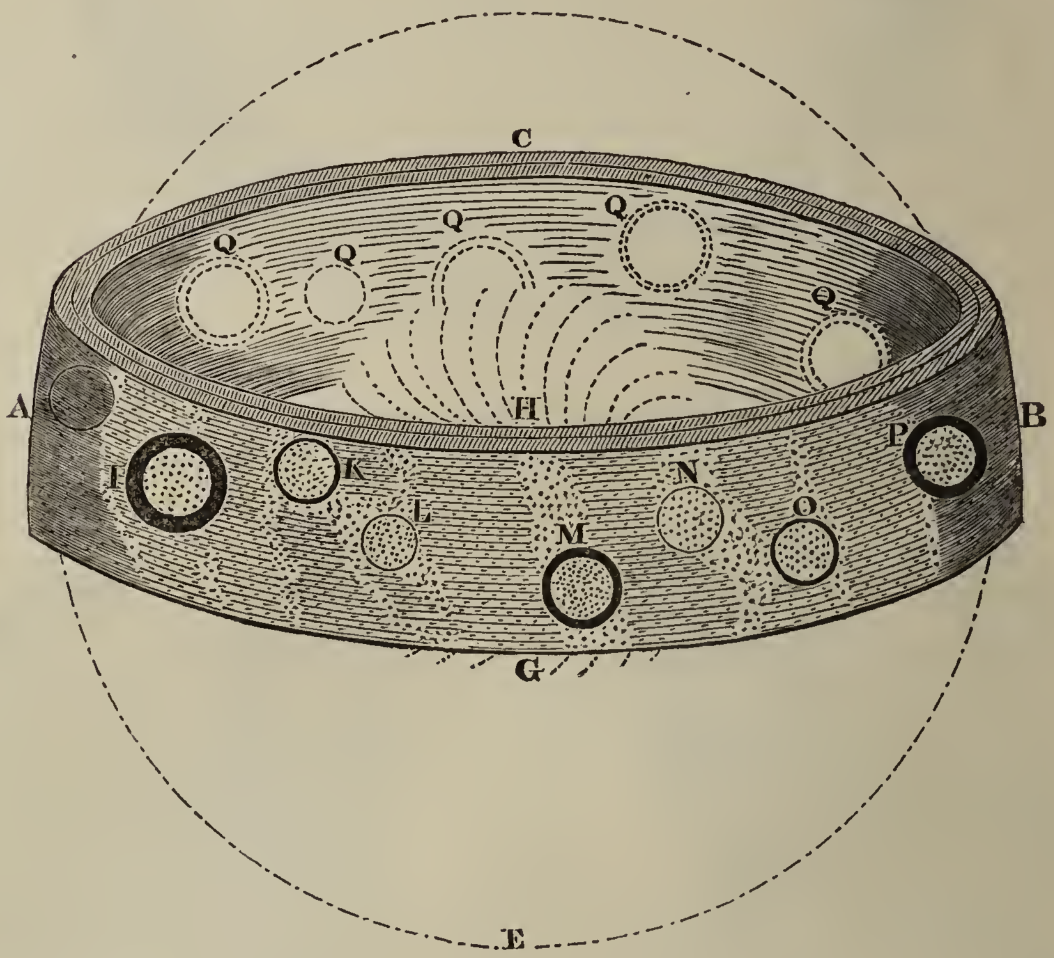


---

* In the original, plate XXVI., fig. 1.
† In the original, plate XXVI., fig. 2.

state of disruption or collapse. One part withdraws itself in an inward direction, as EG and OK, carrying away with it also a part of the actives of the sun, and surrounding them with itself. Another part recedes in an outward direction, such as DPH and NQL, occupying the volume of the element flowing without, and enclosing it by glomerating around it; intermediately however it subsides as it were into itself. A and B are the quarters in which are the poles; the subsidence takes place in all directions toward the equator of the crust or the vortex, and conformably to the situation and motion of the parts in the vortex. Fig. 103 represents the crust collapsed into the form of a zone in the plane of the equinox, about which are situated the bodies A, I, K, L, M, N, O, P, in which is enclosed and concentrated the vortical element. Interiorly however, as at Q, Q, Q, Q, Q, are the bodies in which are enclosed and concentrated the actives of the sun. The zone itself or belt consists entirely of fourth finites. Fig. 104 represents the formation of the bodies

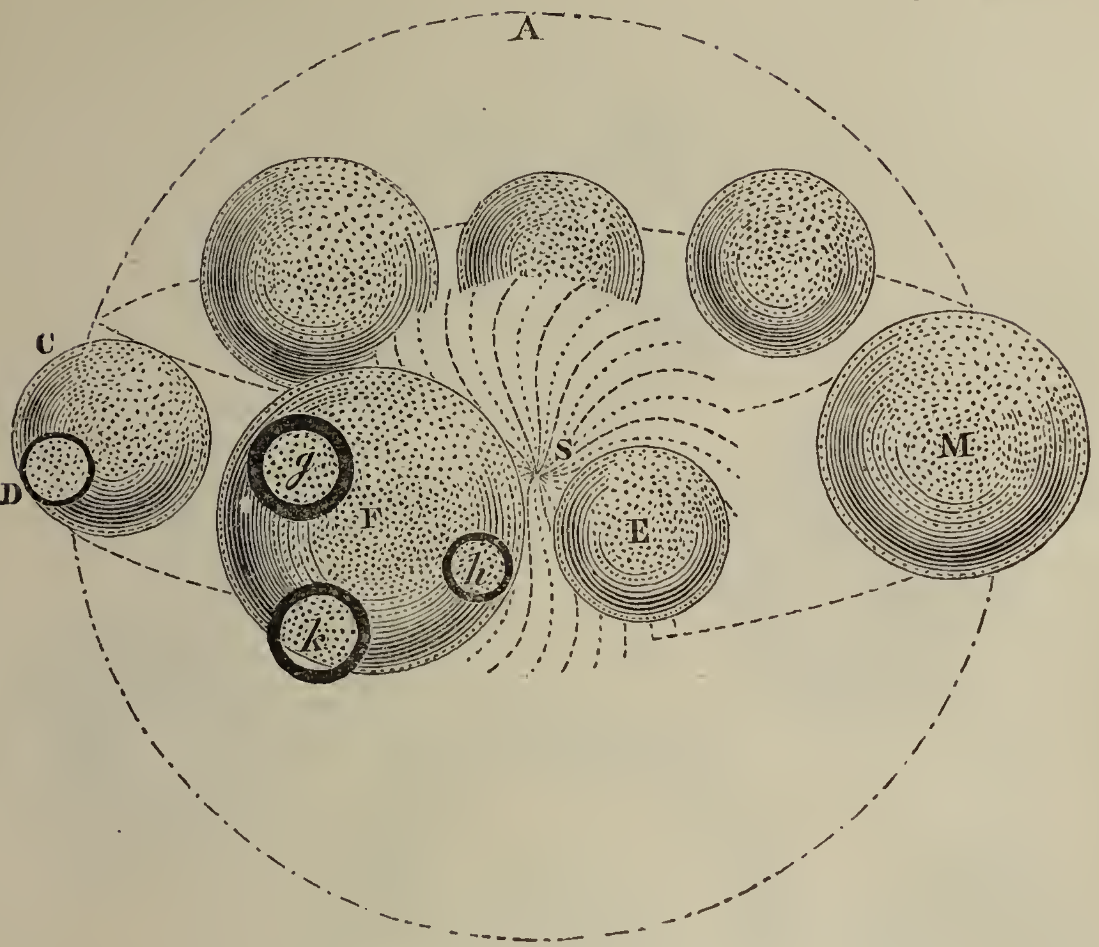
Fig. 103,*



---

* In the original, plate XXVI., fig. 3.

Fig. 104.*



into globes, after the disruption of the zone. To these still adhere partly the lighter bodies, such as *g*, *h*, *k*, D; in which the light vortical element lies enclosed. All the bodies are thus in the plane of the equator, or as appears to the inhabitants of this earth, in the plane of the zodiac.

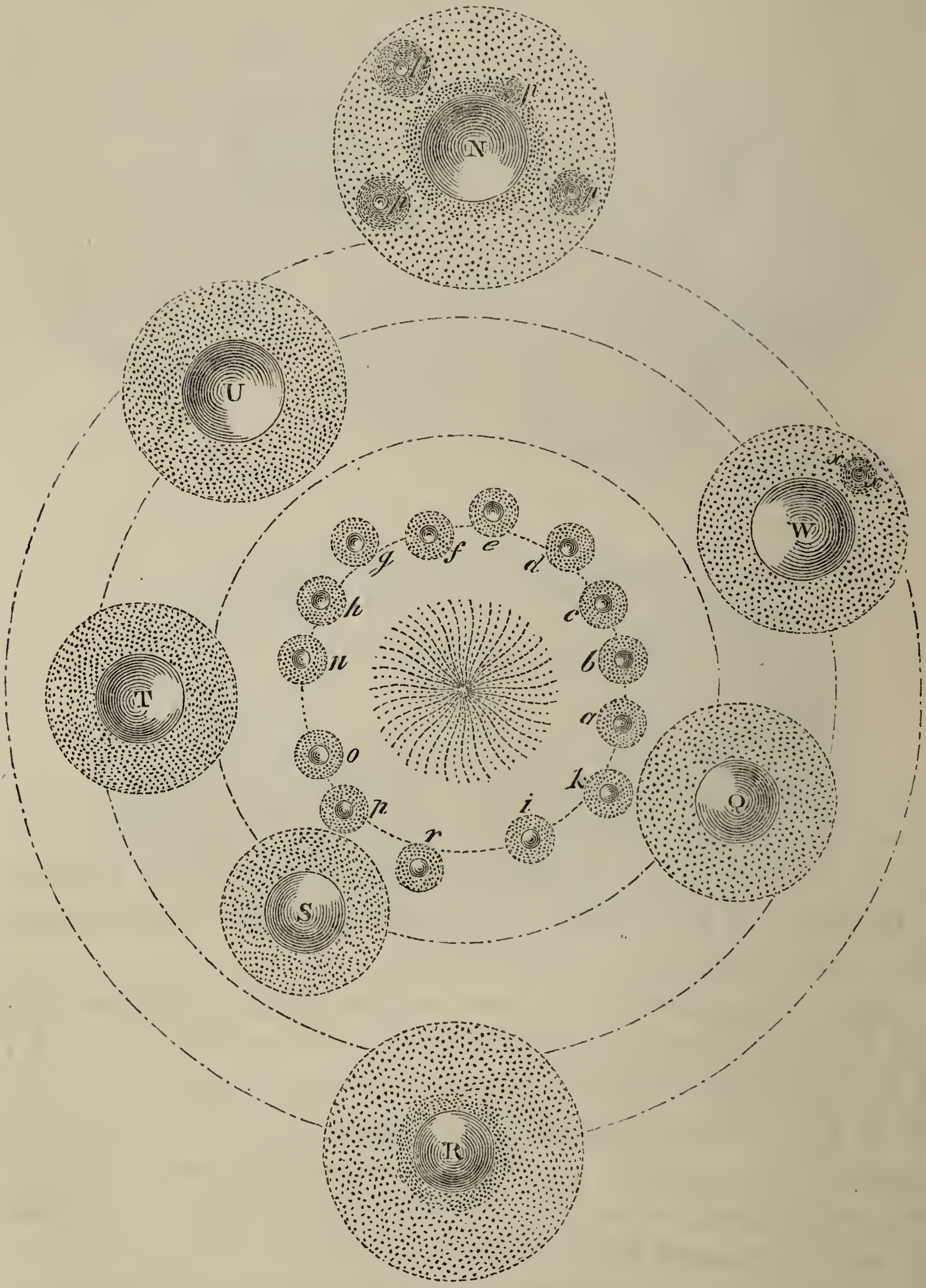
Fig. 105 represents the same bodies issuing from the sun, and veering toward the circle of their orbit, as R, Q, W, N, U, T, S; the lighter bodies accompanying them, such as *p*, *p*, *p*, *x*; all of which become gradually surrounded by the ether in the course of their journey. In Fig. 106 we see represented the excursion of these bodies from the sun, together with the lighter bodies denominated spots of the sun.

Now if it is in this manner that the universal chaos exists, it follows that for a considerable period the sun will be shut out of its vortex; and lie with its beams imprisoned within a crust,

---

* In the original, plate XXVI., fig. 4,

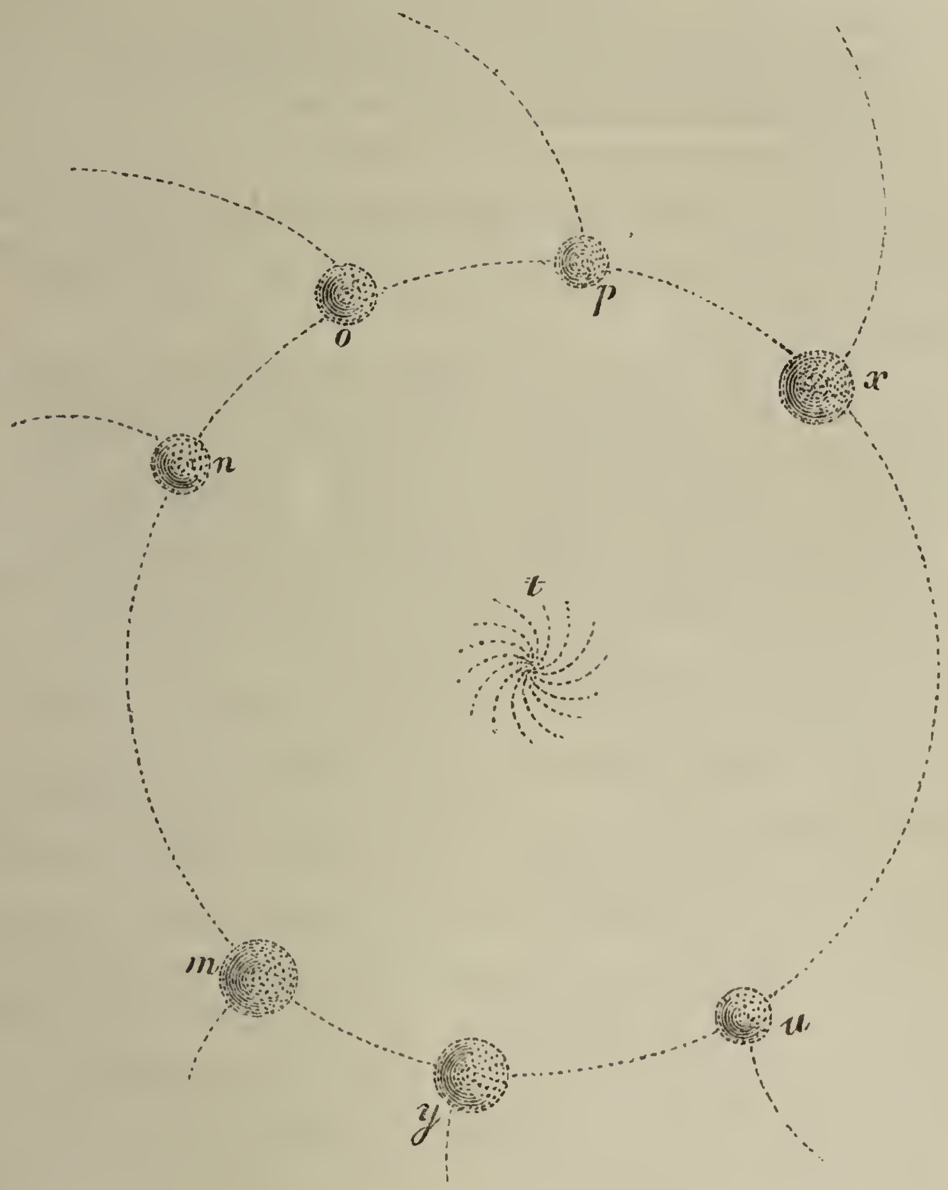
Fig. 105.*



---

* In the original, plate XXVII., fig. 5.

Fig. 106.*



without any elementary expanse into which it can diffuse itself. Accordingly Ovid observes that, 'its terrible aspect was covered with a pitchy darkness.' And in another place, that 'the whole heaven lay buried in shadow induced by pitchy clouds, and that the image of night had doubled the folds of her veil.' Again, when he sings of chaos, that 'Titan as yet afforded no radiance to the world, and the air was unlit.' And again, in the sequel, that now 'darted forth the fiery force of the convex and as yet imponderable heaven.' Thus did the ancient philosophers conceive, that Night and Tartarus were in chaos; and that from Night sprang the Earth the Ocean, and the Heavens.

---

* In the original, plate XXV., fig. 5.

Moses also makes mention of darkness, and of an abyss. But Aristophanes and others come still nearer to our philosophy:

The black-winged Night first lays a windy egg,
Whence in the circling hours sprang wished-for LOVE,
The golden feathers glitt'ring on his back,
Resembling the tempestuous vortices.

Which is the same as if he had thought, that the sun was enclosed in an egg, from which, in a state of revolution, it afterwards emerged.

Nor is this philosophy in want of evidence derived from actual observation, inasmuch as the celestial phenomena appear to confirm it. Stars have been known to come into view, and after a lapse of time, to grow obscure and imperceptible: then again to become visible, and again obscure; so that either they altogether disappear, or else, unless some neighbouring stars should in the meantime occupy their vortex, remain in view permanently. Here then we see the origin of the planets actually imaged forth to the eye. We see, as it were, the same incrustations arising from the compression of the circumfluent elementary parts, and veiling over the star or sun to which they belong; we see also their repeated dissipations and separations. Astronomy is full of phenomena of this kind, and to this very day continues to offer to the eye those representations of chaos of which we have been speaking; forbidding as it were a single doubt upon the subject. I shall here adduce the remarks of one astronomer only; the celebrated David Gregory, who, in his *Elements of Physical and Geometrical Astronomy,* lib. ii., prop. xxx., p. 171, A.D. 1702, thus observes:—

> "In the age of Hipparchus, according to the testimony of Pliny, there appeared among the fixed stars a new one, between which and the celebrated star in Cassiopea, which appeared in the year 1572, Riccioli enumerates the appearance of six other stars. The new star in Cassiopea, which seemed to be of the first magnitude, appeared about the beginning of November, in the year 1572; and continued till the month of March, in the year 1574. This star, as well as the one which appeared in the age of Hipparchus, gave occasion to Tycho Brahe to make observations on the fixed stars; as he himself states in his *Progymnastica,* in which he expressly treats of this new star. In the month of August, A.D. 1596, David Fabricius observed a new star of the third magnitude, which disappeared in two months. In the year

1600, a new star appeared in the breast of the Swan; first observed by other astronomers, and afterwards by Kepler, who gave an astronomical account of it. This star, which was of the third magnitude, continued to be so till the year 1659. (Kepler made observations upon it with large instruments from the year 1638 down to this period.) From the year 1659 it began to decrease in a remarkable manner; and, at the end of the year 1661, had entirely vanished. After an interval of five years, or in the month of September 1666, it reappeared so as to be visible even to the naked eye, and was seen by Hevelius as a star of the sixth or seventh magnitude, in exactly the same situation it had previously occupied. In the year 1604, about the beginning of October, a new star was seen in the right foot of the Dragon, which appeared larger than Jupiter and nearly equal to Venus. This star lasted for a whole year; but after the month of October 1605, became invisible. Kepler published a pamphlet upon the subject. These three new stars, viz., the one in Cassiopea, the one in the Swan, and the one in the Dragon, were seen in the galaxy; which consequently came to be denominated by some the treasury of new stars. Other new stars also have been observed; one, for instance, in the year 1612: this was seen in the girdle of Andromeda by Simon Marius, author of the *Mundus Jovialis:* another in Antinous, by Justus Byrgius, clock-maker to the Prince of Hesse; as also by other astronomers. In the year 1638, John Phocylides Hollward, of Francfort, observed a new star of the third magnitude, or still larger, in the neck of the Whale. The manner in which this star vanished and reappeared every year, but not always at the same time, (though Bullialdus thought it was,) and how after four years it became again finally invisible, may be learnt from the history of it given by Hevelius, and annexed to his account of the planet Mercury, as also from his Annus Climactericus. Cassini found by observation, that the phases of this star recurred after nearly 330 days; for sometimes there was a difference of 15 days in the commencement of the phase, either sooner or later. This star seems to be the same with the one which Fabricius had observed in the year 1612; for the localities of the two coincide. In the month of July, 1670, Hevelius detected a new star of the third magnitude under the head of the Swan; and which, in his catalogue, he assigns to the Little Fox. After a short time it began to decrease, and about the end of August, 1671, entirely disappeared; but in the month of March following it again came into view, at first like an extremely minute star, from which it gradually enlarged to one of the third magnitude. After this it again diminished; so that in the month of September, 1672, it became wholly extinguished, and was never afterwards seen. Besides these, there have been seen other stars of various magnitudes, as of the 4th, 5th and 6th, which were known to the ancients, and were observed also by Tycho Brahe; but which also have, in turn, gradually become extinct, as we may find on examining Hevelius' catalogue. Hevelius mentions four in his *Prodromus Astronomicus;* one star, namely, in the left thigh of Aquarius, preceding the adjacent one in the tail of Capricornus; a second in the belly of the Whale; and another, the first of the shapeless ones behind the beam of the Scales. Other observations upon these stars have been made by French astronomers. Besides all this, the large fixed stars of the first, second, and third magnitude are found to experience considerable changes, in regard both to lustre and dimension; as is evident from the different accounts, given us by various astronomers, concerning fixed stars of the first and second, or second and third magnitudes. And in order that posterity might be the more easily able and without error to judge of the changes experienced by the large fixed stars, Hevelius in his *Prodromus* has recorded a variety of observations made by himself."

From these statements it appears, not only that stars are seen to come into view in the heavens, but that afterwards they form around themselves another element, and in course of time become incrusted; that, in this state of incrustation, being situated among so many neighboring stars which are disposed in their own sphere in regular order, they are unable to perfect any vortex around themselves, and consequently always remain in a state of suspended formation; that hence they become incrusted, continue in their state of incrustation, and thus remain concealed from our view.

CHAPTER V.

ON THE ETHER OR THIRD ELEMENT OF THE WORLD.

Here we again revert to first principles, being obliged to have recourse to repetition, because these principles are always the same and are only two in number, namely, the active and the passive; of which also one is only the cause of the other. Nature constantly retains the greatest similarity to herself, and, as we have above stated, presents herself to us as the same in her largest and least entities; the same in the solar vortex as in a minute volume; the same at her nativity as in her adolescence; the same in the simple as in the compound; the same in one *end* as in the other, and hence also the same as in intermediates. Even did she extend her heaven infinitely beyond its present limits, still she would continue one and the same, were it the will of the Deity that her primitive force should continue the same: that is to say, were nature in this case the same as she is in our world. Nature therefore is similar to herself in the chaos and large compound of actives and finites, and in her elementary particle or most minute compound of actives and finites. And although this huge particle or chaos be discriminated and divided into parts, that is to say, into globes or planets, still does nature remain similar to herself; that is to say, similar to herself in the large individual ens or planet and in the small or finite ens. *Every planet therefore, however great, is nevertheless such as is the finite; or it is only a large finite; the difference between the two consisting only in degrees and dimensions.* A large ens is similar to a small one, nor can nature be in the former different from what she is in herself. A planetary globe consists of fourth finites, which are its individual parts, and which always present themselves as the same whether in a larger or smaller volume or mass; for every individual part possesses the same force derived from the same primitive force in the point, and these individual parts cannot actuate themselves, or finite themselves in a smaller form, (so long as they remain so closely conjoined,) except only at the surface. These individuals therefore, or fourth finites, operate in the large body or system in the same manner as they do in the smaller. *If therefore a planet derives its similitude from its own finite, or its individual parts, it does so more particularly in respect of its tendency to a similar motion, or a similar intrinsical and progressive motion, and a similar axillary motion.* These are the essentials of every finite in its least boundaries as well as in its greatest. That every planet possesses a progressive motion, we shall demonstrate in our theory of the earth, when we come to treat of its polar vibration and the progression of the nodes in the ecliptic, which is the slower in proportion as the finite is the larger or more extensive; for it is not possible but that all the individuals in so large a body, supposing them to preserve the figure of their situation, must occupy ages in performing their progressive motion. Astronomers know perfectly well that the planet possesses an axillary motion; the fact is doubted only by pseudo-astronomers. Indeed we may become eye-witnesses of the phenomenon by observing the planets through the medium of telescopes; we perceive its existence in our own earth, by watching the apparent motion of the sun; hence in this our large planetary finite, we have from a like cause an axillary motion in conformity to the plane of the equator. With regard to the local motion of the planet, there can be no doubt of it, inasmuch as it performs an annual revolution round the sun; a motion which returns into itself by aid of the vortical element, in which it is contained, and which pursues a similar direction; so that in producing the motion of the earth, there is a twofold cause. What therefore we have said of the finites, of the progressive motion of their parts, of the axillary and local motion of the whole, is applicable to our own earth: and all that is said upon the subject in Part I. would here be repeated and applied to the motion of each planet, were it not desirable to avoid repetition. The reader therefore is referred to the theory in Part I., Chap. II., III., IV. and VIII.; and to Chap. III. in the present Part. We may also here apply what we have already said of actives; for *planets which are rendered active by their local motion round the sun, have the same motion as actives.* On this subject the reader is referred to Part I., Chap. V. and VII.; also to Chap. VIII. in the present Part.

When the sun, which so long has been pregnant, has at length given birth to its numerous offspring, then the whole family of planets surround it as a parent, disporting about him in virtue of their inherent and connate motions; and after having arrived at the age of adolescence, take their adieu, in order to pursue their journey throughout his extensive empire. Thus does each one in turn abandon his procreator, and seek the province destined for his own proper habitation. The sons of the great common father divide the vast empire among themselves, but still remain within the limits of his government. To him they look up with filial dependence, and in him acknowledge their origin: morning and night they offer to him as it were their adorations, for from him they first derived their life, and still continue to derive it; thus does he always reserve to himself the supreme authority of a parent. Let us however now bid adieu to the planets, and while we leave them to their rovings, confine our attention to the globe we inhabit. In so doing, let us accompany it from its place of nativity to the orbit which it finally attains; let us see in what manner it invests itself with ether, air, water, and the other entities of which it consists; let us mark the changes it undergoes in its progress towards its ultimate orbit, and by which, through the medium of series, it attains to such varieties; the manner in which, by reason of its vicissitudes and contingencies, the seeds of such a multiplicity of things are produced, and the face of the earth is made to assume an appearance so beautiful, so enchanting, that, as reflected in our world, nature seems to admire her own charms—charms so numerous and varied, as to challenge the admiration of all the inhabitants of the earth.

Hitherto the infant has been left naked, unclothed with any living vesture; and being but of recent birth, is yet in its utmost simplicity, consisting entirely of fourth finites; thus it is homogeneous, uniform, and perfectly regular in its figure. As yet it possesses nothing heterogeneous; nothing cold to disharmonize with anything hot; nothing of one kind in opposition to anything of another; nothing moist in opposition to anything dry; nothing soft in opposition to anything hard: it has weight without weight; nor as yet does it comprise within it the seeds of things whose parts have been ill assorted to each other in consequence of a discordant influence. The earth continues to retain its primeval form; and, as the poets have sung, from the surface to the centre one and the same undiversified aspect. Nay, might we indulge in the language of the ancients, we would say, the family of gods has not yet been born; Jupiter cannot as yet enter into wedlock with Juno, for as yet there is neither ether nor air; neither has Venus or Love, so famed by philosophers and poets, yet made her appearance; much less any semi-deities. Phœbus and Time alone exist, and even these in their infant state. Let us however pass to graver and more useful considerations.

1. *That the fourth finites, of which the infant earth consists, cannot possibly actuate or finite themselves still further; that is to say, they cannot form themselves into similar larger finites, except near the surface; not however between the surface and the centre, because here they have no room for unfolding themselves. That even near the surface they cannot actuate themselves, because the vortical element or first elementary particles flow round, press upon and impede them, and whenever they are set free, immediately absorb them. That the earth thus floats in an elementary volume, or in the vortical element of the sun, with which alone it is now enveloped and equally pressed on every side.* That they cannot actuate themselves, follows from the principles we have before laid down. In order for them to become actives, a space is required, which is either empty or non-resisting; in which, as actives, they may run freely and circumgyrate with all their force, or without hindrance. In the present case however there is an element which serves as an obstacle to them, and which presses upon the earth in all directions; hence having no power to actuate themselves, they are compelled to occupy [*premere*] the surface of the earth, although in every fourth finite there remain the force and quality of tending to move

still further. Moreover, in the vicinity of the sun there are first elementary particles in their highest degree of compression, which consequently press upon the earth and its individual parts in greater abundance and force than elsewhere; but the case is otherwise after the earth has progressed to a greater distance into the solar vortex, where the same elementary particles, exercising a less pressure upon themselves or upon the earth, receive them and allow them greater scope for finiting themselves. Between the surface and centre of the earth however they have no room for unfolding their forces, or for glomerating or dividing themselves into other finites; as we may see illustrated in cases which come within the limits of our own vision. Water, for instance, whose surface we distinguish from the surrounding atmosphere, evaporates and exhales only at the surface, not in the interior of its volume: the same is the case with mercury, as well as with all liquids which at the surface are pressed upon by the atmosphere. In the middle however the volume itself prevents the possibility of such an operation, which both presses and is pressed upon according to its altitude. This however does not prevent every part in the earth, from the surface to the centre, disposing itself into its own proper order.

2. *That these fourth finites flow more at liberty near the surface of the earth, and there only can dispose themselves and have free scope for any given motion. That this is a consequence of the former proposition. That hence they are there occupied by the particles of the circumfluous element, and formed into new elementary particles, which interiorly contain a small volume of the particles of the first element, the fourth finites constituting the surface; that is to say, those finites of which our new orb consists. That these new elementary particles are the same with the ether.* This we see illustrated in the case of water and every liquor which evaporates only at the surface. The fourth finites or individual parts of the earth possess their own inherent and natural force, by means of which they have a tendency to motion; and especially at the surface where the elementary particles of the fluid vortex are contiguous and in perpetual motion, particularly in the vicinity of the sun. From the operation of this twofold cause they convolve themselves into new particles, in which the elementary particles of the vortex are

enclosed, the fourth finites constituting the surface; corresponding to the case of the first and second elementary particles round the sun, of which we have spoken in Part I., Chap. VI., art. 3; and Chap. X. Thus have we new elementary particles entering into the system and constituting a third element, or the ether. Hence it follows, *that in course of time there sprang forth a large quantity of these elementary particles or ether, inasmuch as a large volume of elementary particles may arise from a small volume of finites; and hence the new earth experienced a considerable diminution at its surface, before the whole sphere of ether became perfectly formed around it.*

3. *That inasmuch as this new earth continually rotates round its axis, and exposes once every day its whole surface to the sun; these new elementary particles take their rise all over the surface, are generated over the whole circumference, and do not proceed from one part more than from another; whence the earth, however diminishing at the surface, retains its spherical or elliptical form; and since it has an axillary rotation, the elementary particles just produced are carried into a certain motion, which is the same with that of the earth. That being as it were colligated together by means of this motion, they dispose themselves round the earth, and do not suffer themselves to be carried in any other direction; that also they assume this motion from the period of the first commencement of their sphere down to that of its final completion.* Inasmuch as our earth, which consists of fourth finites, is a single large finite or a compound of individual finites, it has therefore an axillary motion; according to the principles we have already frequently mentioned. Immediately on its elapse from the sun it revolves round its axis, sporting as it were and gamboling in orbital motions like a child around its parent, and thus running off far and wide into the vortical field. This axillary motion occasions an equal absorption of the surface into elementary particles, inasmuch as it diurnally exposes every point of the surface to the sun, and the nearer it is to this luminary, the more easily may the solar rays spread over the surface; the comparative magnitude of the earth, when in close proximity with the huge solar sphere, being insignificant. If therefore the surface be everywhere uniformly diminished, its spherical figure is preserved; but if the diminution be greater

in the zones more directly opposed to the sun than in the cold and oblique, the figure will be elliptical. Another consequence of the diurnal rotation of the earth is this; that as soon as the ether is originated, it immediately pursues the same motion, and in the same manner, as the vortical element surrounding the sun: from the first moment of its existence it disposes itself into a sphere, the centre of which is the earth, its motion being assisted by the element of the solar vortex, which gyrates in a similar manner. Now inasmuch as the gyratory motion of the ethereal sphere commences from the moment of the origin of the sphere, when the quantity of ether is as yet but small and extends only to a small distance from the earth, it follows that the element continues to gyrate during its increase so long as the centre is active. But inasmuch as the element of the solar vortex is highly prone to spiral gyrations, it has a vortical gyration at a great distance from the earth, according to the theory propounded in our First and Second Part; and as it is not possible for the ethereal element to reach the length of this distance, but only to a shorter; the real vortex surrounding the earth seems to consist of the element of the solar vortex.

4. *That the ethereal particles are much larger than the first and second elementary particles: the two kinds of particles differ also in this respect, that the ethereal possess an internal space consisting not of actives but of elementaries, while the first and second elementary particles consist of pure actives, as we have before stated. Consequently that the two kinds of particles are not similar in figure, but that the ethereal are exactly spherical, while the first and second elementaries have poles or polar cones.* That the ethereal particles are much larger than the first and second elementary, follows from their being composed of finites in their surface and of elementaries enclosed in the space within; for if elementaries are enclosed in the particles of ether, the magnitude of the ethereal must exceed that of the elementary particles by several parasangs. We have above shewn that the difference between the two consists in this, that the enclosed space of the ethereal particles does not consist of actives but of elementaries. Thus there are as many active spaces as there are elementary particles enclosed, because in every first elementary there is an active space. The ethereal particles thus par-

take of both principles, the active and the passive, and indeed hence deserve the name of elementary. That they are of a spherical figure appears from this, that interiorly there is contiguousness, or a small volume of figured entities forming a contiguous extense. Thus it is that the enclosed contiguous arrangement gives figure to the surface; and that the surface does not owe its figure to the individual parts, as in the case of the first and second elementaries, in which there is nothing contiguous, nor anything resisting, but only purely acting. And inasmuch as the characteristic of an element is, that it exercises a pressure according to the situation and motion of its parts, namely, equally in every direction, we are obliged hence to conclude, that in consequence of this pressure the figure of the enclosed particles is spherical.

5. *That these new spherical particles cannot but be in perpetual motion. That the first enclosed elementary particles dispose themselves in every manner suitably to the motion of their composite or of the ether, and with the greater exactness in proportion as the ether is in a state of greater motion; that is to say, their disposition is according to the degree of motion, and ordinately from the centre to the circumference. That of the elementary particles thus enclosed, those at the centre are more expanded than those which are near the surface.* The ethereal particles are in perpetual motion, because they are perfectly spherical, as also yielding and elastic, and because they touch each other only in one point. The only circumstance which can mechanically impede and retard their motion is that of contact in several points or at a larger angle; now in a sphere there is no angle but a general or circular one, than which there is nothing more highly accommodated to motion. We have frequently shewn in our First and Second Part, that the first elementary particles dispose themselves to this motion; that in a higher degree of motion they become more compressed; whence in the case of the ethereal particle, as its greatest motion is at the surface, it is consequently more compressed at the surface and more expanded at the centre. Now inasmuch as this spherical compound is moveable not in one direction but in all, it follows that the ethereal particles accommodate themselves to all; there is also a certain centrifugal force which urges them from the centre to the

circumference, and if the motion be equal in every direction, the elementary particles assume a higher elevation towards the surface. This we may see experimentally verified in an exhausted glass receiver or cylinder made to assume an axillary motion, and in which central capilli or threads are found to stretch toward the surface. The case is the same also with other fluids and solids made to assume a rotatory motion. Hence it follows that the central particles are more expanded than the superficial. We may here add also, *that the enclosed first elementary particles assume the position which is the most natural to them, and the more in proportion as the motion of the ethereal particle is more intense; and that in this situation they are insensible to the motion of the surface or of the whole particle.*

6. *That the ethereal particles thus formed may subsist under any kind of motion, and with a perfect aptitude to it; that their surface is expanded and equilibrated between two forces, or is pressed as much from without as from within.* For within it is equilibrated, as we have said, by its elementary particles; without, by circumfluous elementary particles of the same kind, as also by the secondary, and again by a reciprocal pressure. Hence the superficial expanse lies intermediately between two or more forces, just as in the case of the aqueous superficies of which vapor consists. Of this subject however we have already treated in Chap. VI., art. 5, Part I.

7. *That the ethereal particle thus formed and equilibrated is most highly elastic, and hence deserves to be called elementary. That it owes its elasticity however to the enclosed first elementary particles, in which is latent the primitive elasticity. That by aid of the enclosed elementaries it may be expanded, compressed, and also may yield; that it derives its elementary nature from the first elementary particles, and is thus endowed with the character of an element.* The enclosed elementary particles being elastic, so also is the volume of these particles, according to Chap. VI., art. 6 and 45, Part I.; hence also their compound is elastic; the particle also possesses an active and passive force, or both the first principles. From what we have said it is evident, that it owes its elasticity solely to the enclosed elementaries, and not to any space consisting of pure actives.

That in every degree of compression and expansion it is never-

theless exactly spherical, and the more so in proportion to the greater degree of motion which it experiences. It is equilibrated between two forces, the element pressing both from without and within. Hence it can be equilibrated between two elementary forces only in a manner adapted to the natural pressure of the elementaries, or to the forces acting on both sides, the action of which is similar both in a greater and smaller degree of compression; in a greater degree the action is more intense, in a lesser more relaxed; hence in the greater degree of compression the figure is more exactly spherical. Now since the figure of the surface is owing to the contiguity of the enclosed particles, and of those which are circumfluent, it follows that the surface can receive only a spherical figure; the cause being always the same, of course the same effect results. See Part I., Chap. VI., art. 18.

8. *That the ethereal particles and the first elementary differ in this, that in a higher degree of motion the former more and more as it were expand themselves and become less elastic, whence they offer a greater resistance to any external force. That on the contrary, in a higher degree of motion the first and second elementaries become more compressed, and when compressed, become less elastic, and in this case also offer a greater resistance to any external force.* That in a greater degree of motion the ethereal particles as it were expand themselves, see art. 5—7. That under the same circumstances the first and second elementaries compress themselves, or as it were withdraw into themselves, see Chap. VI., art. 17, 20, 21, 22, Part I. Hence it follows that in a state of expansion the former exercise a greater resistance, and the latter a less; and *vice versâ.*

Consequently that the expansion of the particles of ether is more tense [durior] *in a greater motion, and less so in a less motion; that the tension of these particles is always proportioned to their degree of motion, and consequently in every degree they have a greater or less tension.* For inasmuch as they have a tension [*tendunt*] according to their degree of motion, they may be more or less tense in one and the same small space. Thus in a cold place their tension may be less because they are in less motion, in a warm place they may be more tense because they are in a greater motion; the particles therefore would have less tension in water than in air, and between the parts of one kind of liquid more than between the parts of another; between the parts of cold mercury less than between the parts of warm spirit: in the pores of a hard body their tension would be different from what it would be in the interstices of the parts of any element; within one body it would be different from what it would be within another; and so forth. Of this however we propose to treat in a work especially dedicated to the subject.

9. *That under every degree of extension and compression the ethereal particles are most highly mobile; and in their state of tension are most highly active.* The more tense they are the more exactly spherical are they; for the enclosed elementary particles have a greater tension [*magis tendunt*], and thus touch in a fewer number of points, and become as it were highly sensible of every motion. In this state there is nothing repugnant to their motion, nothing but what highly favours and is in mechanical agreement with it.

10. *That both by their tension when they are in the highest motion, and their compression as produced by an incumbent weight, they may be brought to such a degree of resistance that they cannot become more elastic, but like rigid bodies resist every compressing or opposing force.* In a state of motion the enclosed elementary particles dispose themselves from the centre to the surface, and straiten like radii or crests, by applying one pole to another, in consequence of which they become harder and more resisting, as we have already shewn in our Second Part; for if each enclosed particle fits one of its poles to the pole of the other, then one is as it were incumbent upon the other, and one being as it were thus supported by the other, offers resistance; and in regard to their poles they are not yielding as they are in regard to their equators. Moreover in consequence of this situation of the particles, they adapt themselves to a kind of vortical motion; that is to say, to every motion which reciprocally takes place among themselves, and into which they cannot enter without being first disposed into their natural situation as already mentioned. Hence they act according to a law most highly mechanical; the same in fine as the one we have above repeatedly stated, and which is derived from the agreement sub-

sisting between the motion and figure of the parts. The more intense therefore is the motion, the more do they elevate themselves into a contranitent position, or into one of self-protection against any oppressive force; the more erectile is the situation which the particles assume; hence the more do they divest themselves of their elasticity; and the greater resistance do they exercise toward any opposing force, whence the less elastic do they become, the more stubborn and rigid, and consequently the more resisting to any degree of pressure. The same kind of resistency and stubbornness arises also from an extreme degree of compression, as will be shewn in the sequel, after we have made a few observations on the complication and state of the particle under various degrees of compression. Hence the particles become rigid and stubborn according to the nature and degree of the motion.

11. *That these particles can be expanded without motion, and that during this kind of expansion they are not rigid but elastic. The more expanded they are and the more quiet, the more elastic and yielding they are; and the more compressed, the less elastic do they become.* Their expansion is owing to a variety of causes; motion is but one of these causes, in consequence of which they become more rigid; for inasmuch as the expansion of the surface consists in the equilibration of the forces pressing on both sides, so there are causes of expansion arising from these principles also, which may be made a subject of enquiry; as for instance, whether the pressure of a superior volume of particles be less, or there be a less superincumbent volume; whether the weight pressing from without, come from whence it may, be less than the pressure of the volume itself. Suppose, for example, any part of a volume be extracted from a given space by the air-pump or by other means, in this case the volume which is left becomes rarer, and in consequence the force of pressure from without becomes less than the force of pressure from within; a state which is called the rarefaction or attenuation of the volume. In like manner the ethereal particles also may be expanded, whenever the proximate ones are dissolved, and the superficial matter of the dissolved particles escapes into their surface; for this circumstance acts as an immediate cause of expansion, or of the translation of one particle out

of its place among the others which are in the same equilibrium. To produce the compression of the particles, contrary causes concur, but it will be needless to specify them as contraries may be easily inferred from those already adduced. It is only in this manner and from similar causes that moreover a flask or bladder containing air can be expanded or compressed. By heat and motion you may expand a volume which in a state of cold and rest relapses to its former dimensions; you may expand it also by removing the circumfluent parts, or by rarefaction; you may compress it by a multiplication or condensation of the parts. Thus you may see on a large scale what happens on a smaller; in the visible portion of the material world what happens in the invisible; in the whole machine what occurs in the model. That the particles are more or less elastic according to their degree of expansion and compression, provided neither of these be produced by motion, may be seen in Part I., Chap. VI., art. 31. In this case the cause being similar so is the effect; but there is this difference, that the contiguous elementary to which the volume owes its elasticity is within. For if the enclosed elementaries expose their equators to the surface, or if they experience a pressure in the direction of their equators, the most yielding and highly elastic particles recede into themselves.

12. *That in the highest degree of expansion the elementary particles may become disrupted, and cease to be elementary; but that nevertheless the finites, inhering in their surface, and which are now escaping by reason of the disruption, cannot actuate themselves, but must illapse into some of the surfaces of the neighbouring particles, and there like finites continue their motion as before in some other surface; so that by the dissolution of the particles and their illapses into the neighbouring surfaces, there is imparted to these surfaces the power of expanding themselves further, and occupying more space, so far as the quantity of enclosed elementaries permits.* On this subject see Part I., Chap. VI., art. 14, where the same phenomenon is presented to us, together with its causes and effect. The cause of the disruption is the expansion to a degree beyond that which the quantity of particles pressing from within permits; or it is a deficiency of the finites which would have occupied the superficial expanse, and which, if rarified, cannot be in any mutual colligation one with another.

13. *That the fourth finites constituting the surface of the ether, are in a situation perfectly regular; extending by continual spires from one polar point to its opposite; and that by reason of this situation there is a mutual connexion between them; consequently that any motion received by this surface must necessarily, in virtue of the contiguity and situation of the parts, circumfuse itself in an instant, and occupy the whole surface of the particle at one and the same time. That in consequence of this spiral situation of the parts in the surface, these ethereal particles arrive with difficulty at a state of rest; more particularly when rendered the more rigid by motion; in which case they revolve with the utmost rapidity round a centre, in the same manner as the first and second elementary particles round their axis.* Finites cannot naturally dispose themselves into any other than a spiral situation, so as mutually to press upon each other according to the mechanism of their figure and motion. See Part I., Chap. VI., sec. 2, art. 2, 3; also Chap. III., art. 19; Chap. IV., art. 19, &c. Hence the finites which create this surface must always retain this nature, wherever they are, if they are at liberty; they must possess always one and the same character, because they are under the control of their own mechanism and under the necessity of obeying its forces. Indeed, we find the same cause prevailing here as in the surface of the superior elementaries, where also finites constitute the surface; hence it is they dispose themselves into a spire, and this from one point in the surface to another. It is in this manner that they form a contiguous extense, from which arises a unanimity and consent of the parts to one and the same motion; so that the nisus, will, and animus of one are the same with those of the other; the state and sensibility [*sensus*] of one are likewise those of the other. The case is the same with all which have become endowed with the property of contiguity. See Part I., Chap. VI., art. 10, 11, 12. We have here only to state in addition, that inasmuch as these finites are raised to a higher power, and are thus made repeatedly derivative, they become inclined to move themselves not only concentrically but eccentrically, according to what we have said in Part I., Chap. VII., art. 12; consequently that they must by their momenta change places with the pole in this spherical surface. But not to pursue this

subject, lest we should dwell too long on the more recondite mysteries of nature, we may observe; that the effect of this spiral situation is, according to our principles, this general one, that the finites impel themselves into a given motion, and in the case of the particle we are considering, into a central motion; just as the first and second elementary particles were put into an axillary motion; on which subject see Chap. VI., sec. 2, art. 6, 8. Hence the ethereal particles are in a perpetual central motion, more especially if the finites change places as to their poles; they are also in the highest degree of central motion, if in consequence of its motion the particle be tense, and in consequence of their slight degree of contact one offers no impediment to the other. Hence when elementary particles of this kind are in motion, they are for this reason most highly active. For the parts of the contiguous space within are disposed with a view to motion, nor does a looser connexion [*situm*] of these parts in any manner offer any reaction; for it is in every respect most obsequious to the nisus of the surface.

14. *That the surface of an ethereal particle may be doubled, tripled, or multiplied in various ways within, and this too during its state of compression; but that the part of the surface which recedes towards the interiors is convolved into new spherules and bullules, or such as are similar to the larger; and that in a greater degree of compression, the bullar spherules thus formed within are multiplied, and thus multiplied dispose themselves from the surface toward the centre.* That a surface consisting of finites may be doubled and multiplied, we have shewn in Part I., Chap. VI., art. 19; and inasmuch as it consists of finites of a similar nature, therefore the effect is similar. The circumstance of these particles appearing to be formed into bullules or spherules similar to their larger one, and as it were its offspring, arises from this, that there is a volume and contiguous formation [*contiguum*] within which occupies space, and that this volume is similar to itself in its largest and least particles. If there be the same individual parts, there are the same causes, and hence follow the same effects. If finites driven inwardly by compression present themselves to a volume of the same kind, they are in like manner ejected by these in motion into superficial, bullar, or into minute ethereal particles. Thus are these

particles generated within by the larger, in the same manner as the larger are generated from the larger volume. By reason of a like nature and mechanism, like begets like, wherever a like cause is present. If any one desires to institute an inquiry into nature by aid of the principle of similitude, he will always find the object of his inquiry, provided he does not seek for similarity in that which is dissimilar. If therefore, when in the womb of its parent, the progeny begins to occupy space, it will first occupy that which is next to the surface, because it is in that direction that gravity and centrifugal motion tend; in like manner it is the place in which it first has its birth, and where also are the more compressed elementary particles which form it; but the more there are to succeed each other, the nearer to the centre they are compelled to be. Hence also it follows, that *these ethereal bullules nitent within, are, in the state of expansion of the ethereal particle, again set free, and recede to the surface, and enter into the expanse.* For in the expansion of the ethereal particle, all the enclosed first elementaries also expand themselves, and consequently those which are enclosed in these small elementaries, and which, when expanded, are in like manner set free, and recede to the larger surface. It follows also that, *in its highest degree of compression, the entire ethereal particle is at length occupied from the surface to the centre by similar small spheres, and thus ceases to be both elastic and elementary, becoming hard and similar to a kind of material finite.* For if we proceed by similar ratios from one degree to another, so as to arrive at the highest degree of compression, we find the whole particle occupied by the forementioned spherules, losing its elementary nature, and assuming a hardness similar to that of a material particle. Hence in a greater and lesser degree of compression, the particle becomes less elastic, less elementary, till it finally declines into what is perfectly hard and resisting. See the parallel to this in Part I., Chap. VI., art. 21, 22.

15. With regard to the elasticity of the particles, it follows from what we have stated, that *the elasticity of the volume is the same with the elasticity of each particle; that the elasticity of an inferior volume is equal to the weight of the whole superior volume pressing upon it, because the two press and are themselves pressed in proportion to the incumbency of other particles, and*

by means of this incumbency it is that they secede into themselves in the forementioned manner; hence in order for them to sustain the superincumbent weight, their elasticity must be similar to the force and weight of the superincumbent volume. It follows also, that *the elasticity of the compressed volume of these particles is to the elasticity of the dilated volume reciprocally as the volumes; and thus that the elasticity of the compressed volume is rendered stronger than that of the dilated volume, in proportion to the mass or weight of the superincumbent volume.* Still however it is not a consequence from this, that the density of the inferior volume of ether is in like manner proportioned to the density and weight of the superincumbent volume; for the particles of ether, as already observed, grow more and more rigid, or less and less elastic, as they become gradually more compressed; until they no longer yield to pressure as they did while in their state of expansion, a state in which they were most highly yielding. Hence, as above remarked, it does not follow that the density of the volume of the ether is in a like manner proportioned either to the density or weight of the superincumbent volume. The actual ratio of the one to the other will be explained in our theory of this subject.

16. *That the ethereal particles mutually press upon each other according to the altitude or weight of the superincumbent volume. That they press in like manner most equally in all directions, upwards, downwards, and obliquely. That their pressure is also proportioned to the side or area opposed to them at any given angle. That the elastic force of the particle tends also in every direction. That they exercise likewise a similar pressure upon the interior parts of any hard body, whose pores and the interstices of whose texture they are capable of entering and permeating; and that thus it is they keep the smaller parts in connexion one with the other.* This has already been in some measure explained in Part I., Chap. VI., art. 47, 48, 49. We here add, that the ethereal particles are, like the superior elementary, under every degree of compression, similar to themselves in respect of figure; they are, for instance, perfectly spherical, both when compressed and expanded; for the enclosed element acts in all directions toward the surface, and this the more or less, according to the degree of compression, for it exercises always

an equal nitency toward every point or angle of its surface; and inasmuch as it thus equally reacts at all angles, in the same degree in which it is reciprocally acted upon either by pressure or by any other force, there is consequently a perfectly equal reactive pressure in all directions, and in the ratio of the weight of the superincumbent volume: this repressure also is the greater in proportion as the points upon which it acts are more numerous, or in proportion as the area upon which it acts consists of a greater number of points; that is to say, it is greater on a larger than on a smaller area; and inasmuch as the reaction is equal to the elasticity of the particle, hence its whole elasticity tends in every direction, and the effect produced is in the same ratio as the elasticity. Now inasmuch as this particle owes its elasticity to the inclosed particles, which are themselves most highly elastic, we have hence the same ratio of elasticity in the particle enclosing as in the particles enclosed. On this subject, see Part I., Chap. VI., art. 6, 7, 31.

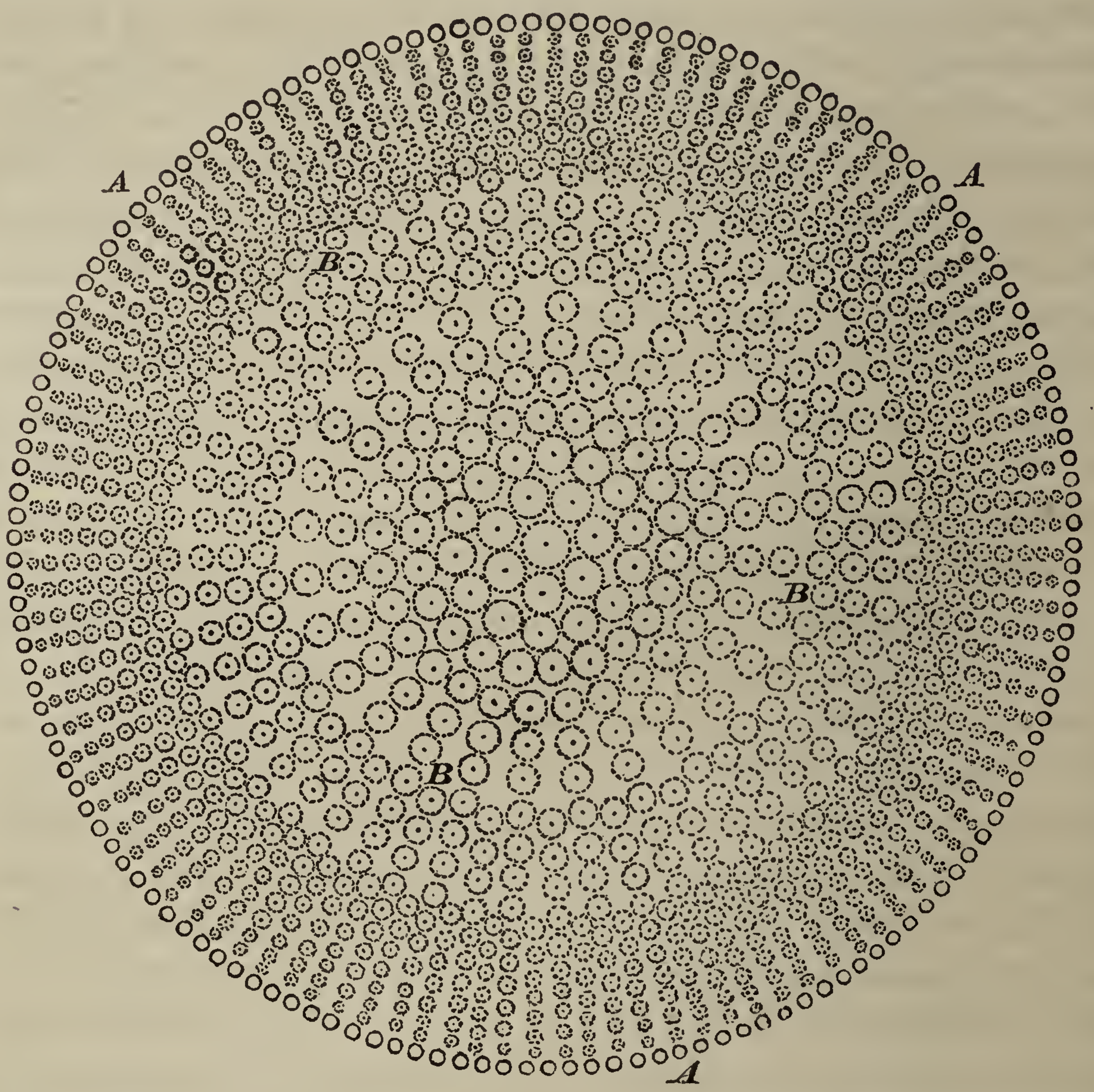
17. *That the motion of the volume of the ethereal particles is the same with the motion of the particles individually. That this motion is perfectly equal in all directions; in this respect differing from the motion of the volume of the first and second elements. That every single particle contributes its own individual share to the motion of the volume; and hence that from the figure and mechanism of the particle we may ascertain the nature of the motion of the volume of particles, and from the figure and mechanism of the motion of the volume, the nature of the particle.* On these subjects however we have dwelt almost to prolixity in the First and Second Parts, and hence we may here omit all further explanation of them. We must bear in mind, however, that the difference in the general motion of the particles is the same with the difference in the figure of the particles. The ethereal particles, inasmuch as they are perfectly spherical, dissipate themselves in spherical directions, or observe a figure of motion similar in every direction; that is to say, they form by their motion a volume perfectly similar to itself, their motory nature discovering itself even to the senses.

18. *That particles moved in volume preserve nevertheless their equilibrium one with the other in their mutual situations, and cannot by reason of any general motion be forced out of their equili-*

brium or natural state. Consequently that in a single volume in motion, there may exist innumerable other volumes, and indeed as many as there are centres or causes of motion, or as many as there are particles. Nevertheless that every single volume arising from motion, diffuses and configurates itself from its centre with perfect uniformity and similarity, according to the geometry of the parts; that is to say, spherically. The motion of the volume is the same with the common motion of the parts. It is as it were a large particle compounded by means of motion: one particle acting upon its proximate in the ratio of its elasticity and pressure; hence one does not disturb the natural position of the other, each maintains the situation which it holds relatively to its proximate, nor is there one which undergoes any change of place, figure, or space, separately from any other. The volume is as it were a large contiguous cohering whole, whose motion is that of its particles [*particulatim motum*]. Thus does the particle in motion remain always in its natural state; no particle loses any portion of its equilibrium, but contributes its own share to the formation of the general equilibrium. But if every individual part of the contiguous whole or volume in motion, be in its own state and remain similar in itself, there is nothing to prevent one volume being formed within another, other volumes within these, and so on continually; for as many may be formed without disturbance or loss of equilibrium as there are centres and individual parts. Thus is nature similar to herself both in causes and causates; thus also in causates causes reëxist, and no causate is produced without at the same time its cause; that is to say, nature is the same in the cause and in the effect. In this manner she operates as it were purely by causes, and is always in her cause in order that she may be called the cause of her effect, that the posterior may be called her prior, the principiate her principle; thus that she may be always one and the same, and preserve the most perfect simplicity. In the immensity of the heavens nature beholds scarcely anything else than her cause, origin, and first principle, and contemplates herself in it as in her simple form. It is only by the degrees, moments, and ratios thence arising, that she confounds us; that is to say, it is her magnitude and minuteness, and hence her profuseness and variety, which overwhelm our senses.

19. We now present to view a delineation of this particle; for unless this ethereal individual be actually submitted to the eye, our ideas of what has been stated will be but obscure. Fig. 107 represents a single ethereal particle in the highest degree of extension, or of motion. The surface is composed of a single series of finites A, A, A. Interiorly are the first elementary particles B, B, B, having an erectile position in accordance with their poles from the centre to the surface. In the middle they are most highly expanded, and are by degrees compressed toward the surface, where they are in their state of least elasticity. If this particle should experience a further

Fig. 107.*

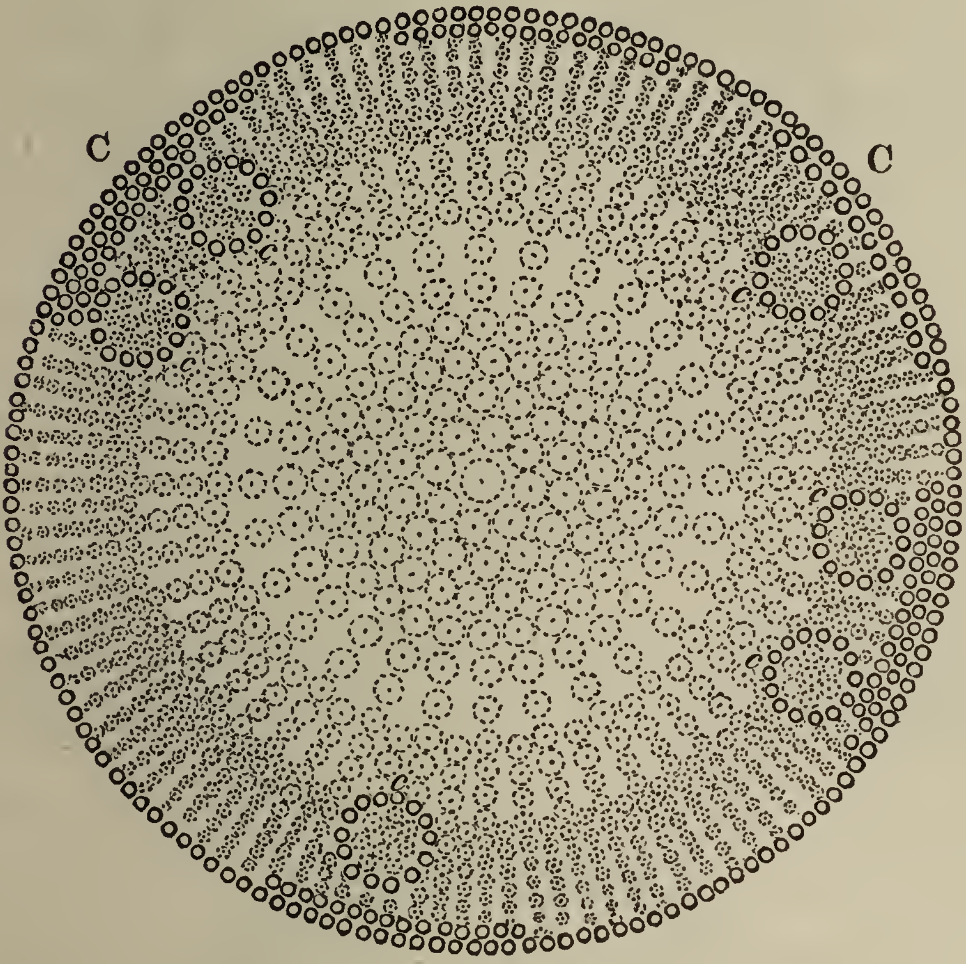


---

* In the original, plate XXVIII., fig. 18.

tension, the connexion of the finites in the surface would be dissolved, and hence also the connexion among the neighbouring particles. Thus in Fig. 108 we see the particle under some degree

Fig. 108.*

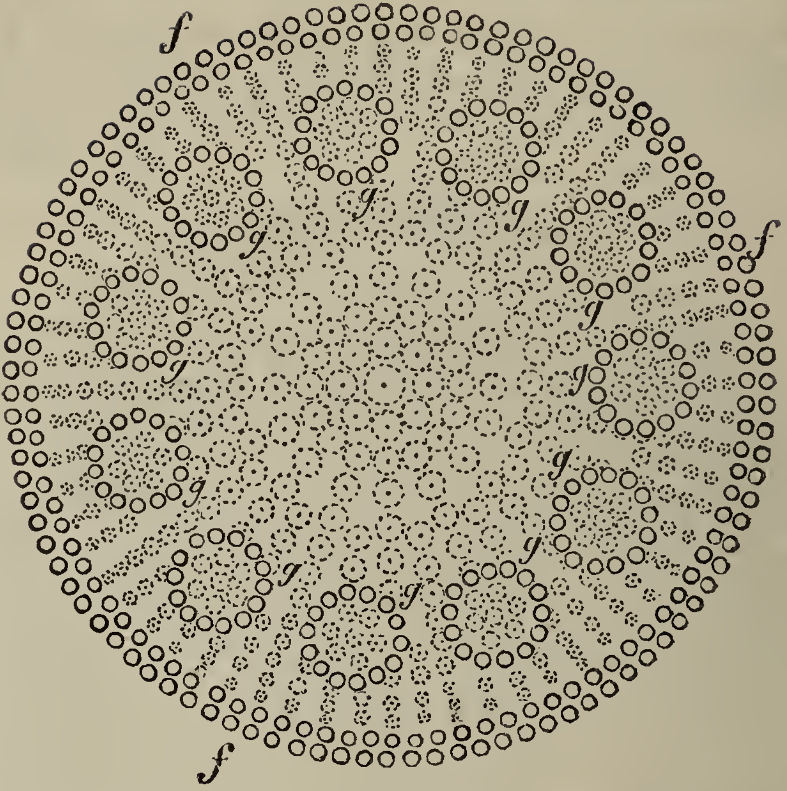


of compression, but still in a state of motion; in which case the surface begins to exhibit a certain degree of complication and to multiply its rows, as in C, C, C; the same surface is also convolved into small spherules, as in *c, c, c, c, c,* the interiors of which are in like manner occupied by the volume which encompasses them without. Thus do these spherules reside interiorly as in the hollow [*alvo*] of the larger; but inasmuch as the elementaries enclosed by these, are almost in the same degree of compression with those which flow without, although there must be a slight difference between the two, it follows that when the exterior elementaries are expanded, so also are the interior; whence the spherules as such are destroyed, and in their free state betake themselves to their parent surface. Again the particle is exhibited still more compressed in Fig. 109,

---

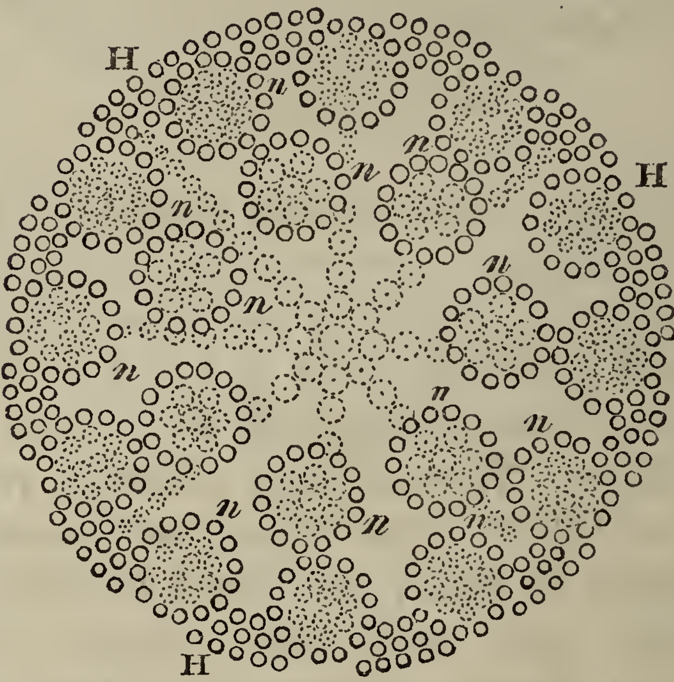
* In the original, plate XXVIII., fig. 19.

Fig. 109.*



where the spherules are still more in number, but are near the surface, as in *g, g, g, g, g, g*. In their state of highest

Fig. 110.†



compression however, as in Fig. 110, the spherules *n, n, n, n, n, n*, extend even as far inwards as the centre. In this state, inasmuch as the first elementaries are almost all consumed in forming these spherules, the particle ceases, in consequence of the loss of its yieldance and elasticity, to be elementary.

---

* In the original, plate XXVIII., fig. 20.

† In the original, plate XXVIII, fig. 21.

20. *That if the volume of ethereal parts flowing from any centre into perpetual equidistant surfaces, pass through any hard body or its more open meatuses, so that the motion of the fluent ether be continued from the other side so as to preserve the same method, course, and mechanism; the body is in this case diaphanous or pellucid; if its passage be irregular, so that the motion is continued from the other side in various manners, the direction of the current being changed, the body is of a white color. That a volume in motion extends itself directly from the centre like radii; and where it cannot penetrate* [transire], *is reflected, and this too at a certain angle; just as all other elastic spherical bodies are resilient from any other elastic or hard body; if however the volume effect its transition, it is inflected and refracted at the same angle of incidence.* It is at this point that nature begins to unfold her operations; to present herself to the eye in diversified forms, although she still remains the same and similar, and only issues out as it were from a certain centre, and forms peripheries at a distance, and diffuses herself to as great a distance as the yieldance and compliance of parts permit. Throughout the whole of the circuit, however, in which nature is seen disporting with her colors, we meet with nothing more than the phenomenon of her hastening directly from a centre and extending around like radii, in the manner of contiguous surfaces: if she encounters a body, she reflects herself at her own given angle, and if she effects a passage through it, she inflects or refracts her radii. Motions may have various origins, or may issue from their centres in various manners; they may extend more or less widely, or from a greater or less space or centre, or from spaces or centres of various figures. A motion may thus be more or less curvilinear, more or less extensive, slower or swifter; it may in its course render itself similar to the moving force, because it may emanate into space from innumerable centres wherever there may be centres. *Thus within one volume in motion there may be similar and dissimilar motions, or motions concordant and discordant, or more or less harmonic; and all these may simultaneously pass through the organs of the eye, and simultaneously and similarly present themselves to the soul.* Similar

and harmonic motions may unite, and more powerfully move their mechanical organs; dissimilar motions may as it were be reduced to their faintest forms, and nature may thus with infinite variety sport before the senses and the soul. Were I to supply the rules of motion under all these circumstances, we should then know the nature of the organs of sight, and the configurated entities from which as from centres the ether directly, obliquely, and reflexly evolves itself. On these subjects therefore we ought to treat specifically, or otherwise in our remarks upon color and light we shall be only in the dark. In first principles we cannot come to the knowledge of effects, without some efficient, or without intermediates. The effect is color: the efficient is the entities which cause the motion: the intermediates are the organs of vision. This subject therefore we reserve for a specific treatise.

21. The doctrine of the ether, or the phenomena caused by ether, may be reduced to the following compendious statement. *Motion diffused from a given centre through a contiguous medium* [per contiguum] *or volume of particles of ether, produces light; for in consequence of this motion the ether is reflected from every entity it meets, and thus an idea of the object is presented to the eye. The central motion of the particles of the ether causes not only a rigid expansion of every particle, but also heat; and if this motion be urged from the centre to the circumferences, it causes light together with heat. If however it be urged from centres toward circumferences so as to become a local motion, but without the central circumvolution of every particle, it occasions light in a cold state. There are corpuscles which resemble a species of effluvia, and which are so small as to be enabled to move only a volume of ether, but not a volume of air; and these, if spontaneously moved, excite light to a certain distance. If they are not spontaneously moved, but are put in motion by means of the tremulation of the parts in any hard body in which they reside, in this case also light is excited, and in like manner electricity, so long as the tremulation continues.* That the motion of the ether, when diffused in all directions from a given centre, or when diffused to equidistant circumferences, occasions the representation of light, is evident from what we have stated; for ether, when put into a general motion or nisus toward the peripheries, occa-

sions itself to be reflected from every object it encounters according to its angle of incidence, and forms as many centres as there are objects to meet it. Hence arises a representation of the species and effigies of things by light; a representation which could not be effected unless the contiguous volume of ether were put into the state of general motion, or effort to general motion, which we have already mentioned. That the central volution of the ethereal particles causes not only their rigid expansion, but also heat, may be seen in this Chapter, art. 8, 9, 10; and Chap. VIII., art. 9, 10, 11, 15. Since therefore local motion, or the effort to local motion, in the ether, is the cause of light, and light is the cause of the species of things represented to the eye, it follows that light may arise from either warmth or cold as a cause.

With respect to phosphoric or meteoric light, as also with respect to electricity, we may observe that both proceed from the same source; namely, from the ether either put into a state of local motion, or else in an effort toward it. The *ignis fatuus*, as it is called, is only a motion dispersed through the volume or contiguous area of the ether, without any rigid extension of its particles. For if there be any corpuscles so small as to move only the ether, like the corpuscles or effluvia for instance proceeding from the magnet, and which move only the second or magnetic element; then I would observe, that by means of the motion of these corpuscles or effluvia, light exists; and if these corpuscles circumgyrate, whither spontaneously or not, provided there be some cause or other to occasion circumgyration, they immediately put the ether in motion and cause light, without the expansion of any ethereal particle; just as is the case with air, which may be moved in volume and contiguously to a distance without the expansion of any particle, and may thus produce sound. The *ignis fatuus* therefore is a local motion of the ether produced by the motion of certain smaller corpuscles, so that the cause of warm and cold light is one and the same. The corpuscles or effluvia we have mentioned, may be put into a gyration and motion either spontaneously, that is to say, *ex se*, or from some internal cause; or else by the tremulation of some hard body, in which they are and from which they proceed. Let us at present confine our attention to the second cause, namely, the tremulation of the hard body in which they are and from which they issue. We say then that the tremulation of this body causes in like manner a tremulation of the parts of the body, and of the minute corpuscles which inhere within it and are fluent without; in consequence of this tremulous motion of the body, the corpuscles in its interior compages being put into a tremulous motion, are impelled into gyres and eddies [*turbines*] as it were, and together with these corpuscles both the ether enclosed in the body and that which is fluent without; for the ether thus put into motion communicates this motion to the circumfluent ether, this motion being assisted by that of the small corpuscles which float in the ether and continually issue from the hard body, and thus the ether becomes actuated into a turbinated motion at a distance from its body, and hence also, as we have intimated, arises light, and in like manner a certain degree of electricity; for there are no bodies existing which are not in some way or other penetrated by the ether, in regard at least to their texture and their larger and looser composition. Hence, by the tremulation of the parts of a body, the motion of the ether diffuses itself around to a distance in the form of a gyre; the motion enters into the texture likewise of the adjacent bodies, and causes these also to observe the same current and eddy of motion, and either draws them towards its own tremulous body or repels them from it, and presents to the eye a play of phenomena similar to that of magnetism. But since magnetism consists in an element and in effluvia more subtile than those of electricity, which consists in the motion of the third element or ether, and in larger corpuscles or effluvia, which are capable of moving only the ether; it follows that, in order for anything to be electric and to attract the lightest objects, a certain motion is required in the ether, and one which is circumgyratory, arising from the tremulation of certain parts. And inasmuch as the ether may at the same time enter into the contexture of the parts, it follows that the ether thus in motion and penetrating these parts, can bring them into the same gyratory motion with its own. This however would not be the case, if instead of being in the ether the motion were in the air, which does not easily enter the texture of the harder bodies. Phosphoric light therefore, as well as electricity, depends upon the tremulation of the small and subtile parts of a body, from which proceed effluvia of the same nature, putting in motion only the ether: the longer therefore this body can thus tremulate, the more electrical it is [*eo melior electricitas*], the more it abounds with subtile effluvia of a like nature, the more perfect are the electrical phenomena [*eo melior apparet electricitas*]. If the body, although it be tremulous, yet possesses no effluvia of this kind, so neither can it give out any light or electricity. On the other hand, if the body abound in these effluvia, but its small parts cannot continue tremulous for any length of time, it is then destitute of light and electricity. The same phenomena may be produced, if one body be highly tremulous but does not possess effluvia of the same kind, and another body be not tremulous but abounds in effluvia of this kind; that is to say, if the two bodies thus differing be rubbed one against another. There are numerous other observations which might here be made, but which I omit, in consequence of having no experiments to confirm them. I might, for instance, dilate upon the manner in which a sphere becomes formed by these gyratory motions; upon the nature of this sphere; and upon the manner in which the elementary particles dilate, compress, undulate, and compound themselves within this sphere, so as to invite and attract into it other and lighter bodies.

22. In this way then do we see that our orb is surrounded with an ethereal aura, and in this state bids adieu to its parent sun, and sallies forth into the immense vortical region which lies before it. Still however far and wide be the range of its orbit, it remains under the eye of its progenitor, under his beams as it were, and within the sphere of his presence; for between the sun and the earth there is that contiguity of expanse by means of which one is enabled to be present as it were to the other. However far asunder therefore they may be in locality, they are not so in relationship. The earth being as yet clad only with an ethereal vestment, is now capable of presenting itself to senses adapted to its perception, beauteous and fair as a newly-wedded bride, discriminated and diversified by colors, provided only there be supplied origins and media, or a corresponding organic form, which may adapt its motions to its

own nature. For the want of these intermediates and causating entities, notwithstanding all its variety, the earth as yet remains simple and uniform. Indeed, our orb is hitherto as it were naked, undistinguished by variety; as yet possessing only one uniform monotony of appearance and color, to which we may add the azure or celestial tint proceeding from the sidereal expanse with which the earth is surrounded. As yet there is no air, nor in this air any Aurora, which arrayed in her glow of colors may lead on the morning and evening, or open and shut the gates of heaven and earth to Phœbus: there are no dews and clouds, in virtue of which, with her saffron wings, Iris may display her many-colored arch in the sky; no groves or woodlands bedecked with flowers; no green, violet, scarlet, or roseate hues sprinkled over the fields; no sulphurous or metallic substances to contribute their mineral and vivid lustres; much less any living creature, whose organs being formed to corresponding motions, may receive into them these external varieties, and communicate their pleasurable sensations to the soul.

CHAPTER VI.

ON THE FIFTH FINITE.

We now come to interrupt the course of the subject with a few observations on the nature of another kind of finite. Indeed, this whole volume of the *Principia* would seem to be filled only with finites, actives, and elementaries; for as often as we leave the subject, we somewhere or other again resume it, so that I am perpetually leading the reader over the same ground. Indeed it must be acknowledged, that in a work professedly treating of first principles, I can do scarcely anything without perpetually recurring to first principles, as contained for instance in the beginning of this volume. Thus we are under the necessity of always saying the same thing over and over again; in the case of derivatives similar to what was said in that of primitives; of composites, similar to what was said of simples; of effects, similar to what was said of causes. Nature is always in her cause when she is in her effect, and reciprocally in her effect when she is in her cause; for both are in perfect conjunction with each other: hence it is that she is always in communion with causes; so that if you seek her in the effect you will find her at home in her cause. If when she is invisible you seek her in the visible world, she will never disappoint you, but there present herself as visible before you. Thus will she never elude the eye, nor hide herself within mysterious shrines, but ever be most intimately present, and perpetually about and around both yourself and your senses. Let us then institute an enquiry into the finite we denominate the fifth, in which the point is raised to its fifth degree or power: and in which it is perfectly similar to the other finites of which we have so frequently spoken, differing from them only in degree and dimension.

With respect to the origin of this finite it follows from our principles; that *it has its origin where there is a quantity of finites of the fourth genus, in the place where the latter can unfold and mutually finite themselves. And inasmuch as these fourth finites are in the present case no where else than in the planets or in this earth, nor can unfold and finite themselves in any other place than at the surface of the earth, and not even between the surface and the centre because they have there no room for so doing, it follows that these fifth finites must have their origin at the surface of the earth, at some distance from the sun, where the pressure of the vortical element is not so great as it is in the vicinity of the sun.* Thus do we arrive at the origin of the finites of the fifth genus, at a distance from the sun and near the surface of the earth. For, as we have already observed, in the vicinity of the sun, the pressure of the elementary particles is too great to allow of it; and hence we must conceive of the fifth finites as having their origin at a distance from the sun. Now inasmuch as these finites are similar to those already mentioned, so they are endowed with a like progressive, axillary, and local motion; they in like manner present themselves as active and passive, and in like manner constitute the surface of some elementary particle. That they constitute the surface of a particle of air, and supply fire with its element, it is my intention to shew in the sequel.

CHAPTER VII.

ON THE AIR OR FOURTH ELEMENT OF OUR SYSTEM.

Let us now proceed to trace still further the course of our globe; let us follow it into that vortical region which it traverses as the mighty empire belonging to its parent; let us mark the concomitant circumstances of its journey, the various changes it undergoes before it arrives at its destined orbit. Now it would seem as if it were requisite that it should go through an infinite number of vicissitudes, before it could become compounded of so many series simultaneous and successive. At present its state is that of nakedness and simplicity; consisting as it does only of individuals of one genus, and but just clad with an ethereal vestment; and inasmuch as, according to our principles, it was only in a state of nudity and simplicity that it issued forth from the place of its nativity, it is necessary for it to experience a great variety of vicissitudes before it can become invested not only with ether, but with air, water, mineral and earthy incrustations of diversified kinds; or with such a beautiful garniture of herbs, plants, flowers, waving corn, and shrubs as it now possesses; before also a rational creature like man can be introduced, as a spouse into the chamber of his partner, into a world abounding with all these delights; the results of varied series and of the vicissitudes the earth has undergone. Let us see then in what manner the earth becomes cinctured with air, in what manner Juno is given in wedlock to Jupiter her brother. For the ancient philosophers feigned that Jupiter presided over the ether, and Juno over the air; that consequently the two lived in conjugal union not far from the earth. They likewise feigned that each sprang from the same parent, that the brother married the sister; thus conveying in an emblem principles of philosophy not very remote from those we are now delivering. With regard to the air it follows from what we have said, that it could derive its origin only in successive order, after those entities are produced of which it is to consist. In the preceding chapter we stated, that a new genus of finites arose at a distance from the sun; we mean that of the fifth finite, which is perfectly similar to those which preceded it; being capable of becoming both active and passive, of entering into the surface of an elementary particle, and of flowing through its surface in the same manner as the fourth finites flow through the surface of the ethereal particle. From the connexion therefore subsisting between the two, it follows, that *air consists superficially of fifth finites, and that within it are enclosed the first and second elementary particles; that air is thus perfectly similar to ether, from which it differs only in degrees and dimensions.* For ethereal and aërial particles are similar to each other in regard to their surface; inasmuch as fourth finites enter into the surface of the ether, and fifth finites into the surface of the aërial particle; and the fifth being of a similar nature with the fourth, they are capable of flowing through the surface in like manner. Moreover these particles are similar in regard to their internal space; for the first elementaries fill and constitute the space of the ethereal particle, and the first and second elementaries that of the aërial; and inasmuch as first and second elementaries are similar and differ only in dimension, it follows that they produce similar effects upon the surface: they differ therefore only in dimension, and consequently in degrees and momenta. It likewise follows that the second elementaries occupy the internal space of the aërial particle, inasmuch as they are larger and can operate upon fifth finites or those of a larger dimension, and may convolute and form them into surfaces; but the first elementaries are incapable of doing this except in relation to the fourth finites. *With regard to their locality, the origins of the ethereal and aërial particles are similar; that is to say, they are near the surface of the earth, where, as we have observed, the ethereal particles had their origin.* Now all things must proceed from our globe in successive order; consisting as it does of individuals of a single genus. Everything which is in it is homogeneous. There is as yet no such thing as dissimilarity; hence nature must derive and multiply herself from what is similar, in successive order; we cannot therefore assign to the air any other place of origin than to the ether. *With respect to the mode of their origin, the aërial particles originate in a similar manner to the ethereal; that is to say, among the first and second elementary particles;* from which the aërial are convoluted and conglomerated as it were into new vaporous combinations; like water and other liquids. For the fifth finites cannot issue from the surface of the earth without operating similarly to the ether, and being converted into an aërial state. *The aërial and ethereal particles are consequently similar in form, and differ only in magnitude and dimension.* For the fifth finites have entered into the surface of the aërial particle, and the first and second elementaries into its internal space; if therefore its surface be thus pressed on all sides, namely, by a volume of elementaries of the same genus, the aërial particles must necessarily be exactly spherical; for when the enclosed volume presses, conformably to its nature, in every direction upon the surface, and upon this surface there is an equal pressure from without; then the ethereal particles press also from without, and hence it follows from reason and experience that in every degree, both of expansion and compression, they have a spherical form; nor can they in any manner recede or be forced out of this figure, as long as the elementary particles which are without and those which are within retain their elementary nature, so as to press equally in all directions upon the particles they meet. Since therefore both the ether and the air in respect to their origin, locality and mode of their origin, as also to their figure, are so similar, they may readily be called, according to the philosophy of the ancients, akin to each other; and well may it be said that the sister married the brother, and resided with her in conjugal union in one and the same place.

Inasmuch as the ethereal and aërial particles are similar to each other and differ only in dimension, all the qualities of motion and figure which we have adduced on the subject of the ethereal particle may be transferred to that of the aërial, and may thus be collected into the following summary;

provided we bear in mind the difference in regard to degrees and dimensions.

1. *That in the course of time there is produced a large abundance of these elementaries or of air, since from a small volume of finites may originate a large volume of these elementaries; and that our new orb, thus continually decreasing as to its surface, becomes considerably lessened before the whole atmosphere around it can be perfectly formed.*

2. *That inasmuch as this new orb continually rotates round its axis, and in the space of a day exposes the whole of its surface or circuit once to the sun, so these new elementary particles, which have their origin in its surface, are generated throughout the whole extent of it, and do not proceed from one part of it more than from another; and thus that our earth, however diminished in mass, still retains a spherical or oval figure.* See Chap. V., art. 3.

3. *That these spherical particles cannot but be in perpetual motion. That the first and second enclosed elementary particles dispose themselves in accordance with the motion of their composite or air; and this with the more facility and aptitude in proportion as the air is in a greater motion; that is to say, they arrange themselves according to the degree of motion in an orderly manner from the centre to the circumference; that the elementaries thus enclosed are at the centre more expanded than those at the surface. That these enclosed elementaries are thus in their natural situation; a situation which becomes the more natural in proportion as the motion of the particle is the more intense; that in this situation also they are not sentient of the motion of the surface or of the integral particle.* See Chap. V., art. 5.

4. *That the aërial particles thus formed may subsist with a perfect aptitude of their forces one to the other, under every kind of motion; that their surfaces are equilibrated and expanded between two forces, being as much pressed from without as from within.* See Chap. V., art. 6.

5. *That the aërial particle thus formed and equilibrated is highly elastic, and deserves to be called elementary. That it owes its elasticity however to the enclosed first and second elementaries, in which is latent the primitive elasticity. That it may thus be expanded, compressed, and may yield, simply by aid of the en-*

closed elementaries. That still in every degree of compression and expansion it retains a most exact sphericity; and the more intense their motion the more perfectly spherical they are. See Chap. V., art. 7.

6. *That the expansion of the particles of air is more tense in a greater motion and more lax in a less motion: that these particles are always in a state of tension according to their degree of motion, and thus under every circumstance have a greater or less degree of tension. That in like manner they are, under every degree of extension and compression, most perfectly mobile; but that in their state of tension they are most highly active.* See Chap. V., art. 8, 9.

7. *That both in their state of tension as produced by the highest motion, and their state of compression as produced by a superincumbent weight, they may arrive at such a degree of renitency as to be no longer elastic; but like hard bodies may resist every compressing or assailing force.* See Chap. V., art. 10.

8. *That even without motion they may be expanded, and that in this state of expansion, produced without motion, they are not rigid but elastic; that the more expanded and the more at rest they are, the more elastic and yielding are they; and the more compressed they are, the less elastic are they.* Chap. V., art. 11.

9. *That in their highest degree of expansion they may be disrupted and cease to be elementaries; but that the finites which occupy the surface and escape in consequence of the disruption, cannot actuate themselves, but must immediately illapse into the surfaces of the neighbouring particles, and there continue their motion in another surface like finites as before; that thus by the dissolution of the particles and their illapses into the neighbouring surfaces, the neighbouring particles have the power of further expanding themselves, and of occupying as much more space as the quantity of enclosed elementaries permits.* See Chap. V., art. 12.

10. *That the fifth finites constituting the surface of the air, are arranged in the most regular order from one polar point, as it were, by continual spires to the corresponding opposite point; and that in consequence of this situation of the finites there is a mutual connexion between them; hence it follows that a motion received by the surface necessarily circumfuses itself instantaneously, in consequence of the contiguity and situation of the*

parts; and simultaneously occupies the whole surface of the particle. That by reason of the spiral situation of the parts in the surface, these aërial particles are with difficulty brought into a state of quiescence, particularly when rendered more rigid by motion; nor can they help having a rapid central circumvolution in the same manner as the first and second elementary particles rotate round an axis. See Chap. V., art. 13.

11. *That the surface of the aërial particle may be doubled, tripled, or variously multiplied interiorly, and this during a state of compression; but that the part of the surface which recedes toward the interiors is formed into new spherules and bullules similar to the larger; that in a greater degree of compression these bullar spherules formed within, are multiplied; and thus multiplied dispose themselves in a direction from the surface to the centre. That these bullar particles, which during their expansion are interiorly in a state of nitency* [nixæ], *become again set at liberty, recede to the surface, and enter into its expanse.* It likewise follows, *that the aërial particle during its highest degree of compression becomes at length entirely occupied by small similar spheres extending from the surface to the centre, and ceases to be elastic and elementary, growing hard and similar to a material finite.* See Chap. V., art. 14.

12. *That the elasticity of the volume is the same with that of each particle, and the elasticity of an inferior volume is equal to the weight of the whole superior and incumbent volume; because it is according to this incumbency that they press and are pressed; that it is by reason of this incumbency that they recede into themselves in the manner we have mentioned; that hence in order for them to sustain the superincumbent weight, the elasticity of these particles must be similar to the force and weight of the superincumbent volume.* It follows likewise, *that the elasticity of a compressed volume of these particles is to that of a dilated volume, reciprocally as the volumes. That the elasticity therefore of the compressed volume is rendered stronger than that of the dilated volume, in proportion to the mass of the volume or weight of pressure. That still it does not follow, that the density of the air below is in like manner proportioned to the density and weight of the superincumbent volume.* See Chap. V., art. 15.

13. *That the aërial particles reciprocally press upon each*

other according to the altitude or weight of the incumbent volume. That in like manner they exercise a perfectly equal pressure in all directions, upwards, downwards, and obliquely; as also a pressure proportioned to the side or area opposed to them at any given angle, and thus that the elasticity of the volume operates in all directions. See Chap. V., art. 16.

14. *That the motion of the volume of aërial particles is the same with that of the particles themselves, and is perfectly equal in all directions; that every single particle also contributes its own share to the motion of the general volume.* See Chap. V., art. 17.

15. *That when the aërial particles move in volume, they nevertheless preserve their equilibrium among themselves, and remain in their mutual situation; nor can they by their general motion be forced out of their equilibrium or natural state. That consequently within one volume in motion there may exist innumerable volumes; as many indeed as there are centres or causes of motion, or as there are particles; and yet that every single volume arising from motion diffuses and configurates itself from its centre in a perfectly uniform and similar manner, according to the geometry of its parts; that is to say, in a spherical form. That the volume of aërial particles, however, moves much more slowly and to a much smaller distance than the volume of ethereal particles.* Chap. V., art 18.

16. *That the aërial volume when in motion extends itself directly from its centre like radii, and that when meeting with any obstacle which it cannot pass through, it is reflected and is resilient at the angle of incidence, like all spherical elastic bodies when impinging upon another elastic or hard body.* See Chap. V., art. 18.

17. Inasmuch as between the ether and air there is a difference in regard to degrees and momenta, it will follow that the tunics of the body which are organized to imitate in their motions those of the air, such as the tunics and tympana of the ear, will be of a crasser organization than those which receive and imitate the motions of the ether; such, for instance, as the eye; and that the organs which carry the motion from the coarser tunics to the more delicate will be of a different kind. Whatever the eye perceives in the ether, of this the ear is percipient in the air; whatever the ether presents to our organs by

means of colours, the air presents to us by means of modulations and sounds. Thus nature is always the same, always similar to herself both in light and in sound, in the eye and in the ear; the only difference is, that in one she is quicker and more subtile, in another slower and crasser, exhibiting herself to our various senses by means of her various degrees and momenta, and being as perceptible to sense in one medium as she is in another. How admirable are the varied and sportive movements of nature! How charming and delightful does she render herself solely by her varieties in the motions of her elements; being as beautiful in the ether by the play of her colours as she is harmonious in the air by the modulations of her sounds! What gratifications does she afford us in the diversified operations of her living machinery!

In addition to what has already been said, we may observe that in Chapter V. we have also stated with regard to the ether, that *within one volume in motion there may be similar and dissimilar motions, concordant and discordant, more harmonic and less harmonic, all of which may simultaneously traverse the organs of the eye, and simultaneously and similarly present themselves to the soul.* See Chap V., art 18.

Inasmuch as the air is similar to the ether, the aërial particle may be represented by the same figure. Thus in Fig 107 (p. 292), we may see an aërial particle in its highest state of expansion. A, A, A, A, are fifth finites; B, B, B, B, are first and second elementaries extending from the centre to the surface and erect as to their poles. In Fig. 108 (p 293), the same particle is represented as under a degree of compression in which small aërial spherules are produced within; in Fig. 109 (p. 294), the particle is in a yet higher degree of compression; and in Fig. 110 (p. 294), the compression is the greatest.

CHAPTER VIII.

ON FIRE, OR THE ACTIVES OF THE FOURTH, FIFTH, AND FOLLOWING FINITES.

We have now described the earth as at length clad with ethereal and aëreal vestments, and thus issuing forth into the vast region of the solar vortex, encompassed with elements of two different kinds; it is no longer therefore in that state of nudity in which it first came forth from the womb of the solar chaos. We are now introduced to Jupiter and Juno, the two principal deities described by the ancient poets and philosophers; and we have seen how the sister has become wedded to the brother. As yet however Jupiter brandishes no lightnings, he is unarmed with the fire with which he is to make his entrance into the chambers of Juno; there are no torches as yet to precede his steps. We come now to explain therefore the nature of the fire of our earth; the nature of that fire which is subtile and penetrating or elementary, as also the nature of that which is less subtile, or the common atmospherical and culinary fire. Without fire all things would be torpid, the air would not be stirred into motion, neither would the ether; consequently without fire or its like there would be no productions of new series to bring the earth to its ultimate perfection, no production and secretion of minerals, no growth of vegetables out of the mineral kingdom, no living creature partaking of the elementary, mineral, and vegetable kingdoms; hence, before passing to other subjects, it will be necessary to lay before the reader the genesis of fire.

1. From the connexion of our principles one with the other,

it follows, *that finites of every power and dimension may actuate themselves, provided they have space for so doing, or for running freely, naturally, and without retardation into their respective circles; provided also they are not implicated in any circumfluent elementaries, and become convoluted into surfaces or new bullar superficial or elementary particles.* That finites of every kind may be rendered active, provided space be granted them in which they may perform their excursions and circles, may be seen in Part I., Chap. V., art. 1, 2, 3, 4, 5, 6, 7; provided also there be no elementaries to divert their course into new particles, on which subject see Chap. V., art. 12. Consequently the fourth and fifth finites cannot actuate themselves in a volume of the elements of the first and second, without immediately being converted into new elementary or ethereal and aëreal particles. For they have no space for their excursive motions, inasmuch as elementaries are present to impede them, and to convolute them, while in the state of actuating themselves, into new surfaces; as in the case of ether or air when converted into water or other liquors.

2. Now since all finites are similar one to the other, as also all elementaries, so likewise are all actives; nor can they differ from each other except as to dimension, and consequently as to degrees and momenta: since therefore finites, of whatever power and dimension, may actuate themselves, the actives thence arising will be of a nature similar to that of the finites, because possessing a similar derivation. Hence the actives of the first, second, third, fourth and fifth finites are perfectly similar one to the other, and according to their natural state of nitency tend to similar eccentric gyres. With regard to the actives of the first and second finite, they constitute, as we have already observed, the large active solar space. We have also observed that there are no actives belonging to the third finite, but that all are themselves third finites, and constitute the surface of the second elementary particle. See Part I., Chap. VII., sec. 2, art. 9. We now come to shew that the actives of the fourth finite create subtile elementary fire, and the actives of the fifth finite, or fifth finites made active, create the common culinary or atmospherical fire.

3. Inasmuch as the mechanism and nature of the actives of

the first, second, and third finite is similar to the mechanism of the actives of the fourth and fifth finite, and differ only in regard to dimension; hence before we treat of the mechanical principles of fire, we must repeat the principles formerly laid down when speaking of the actives in Part I., Chaps. V. and VII.; otherwise we shall meet with some difficulty in arriving at the knowledge of the two kinds of fire. To assist the reader in his ideas of this subject, I shall here transcribe the principal heads of what is there stated on the subject of actives.

All the actives of one kind flow with one and the same velocity, neither less nor greater; they always describe similar gyres and circles, nor can they form any either less or greater. See Part I., Chap. V., art. 7; Chap. VII., art. 10, 11.

In the active there is nothing substantial, with the exception of that only which is circumfluent; nevertheless a surface may be represented by motion the same as if it consisted entirely of substantials; and there is no point in the surface of the active which can be truly called substantial beside the one where the fluent substantial is itself present. Part I., Chap. V., art. 8.

Every such active is most perfectly active, and also endowed with a considerable power of acting upon the proximate finites; nor can there be conceived in the surface any point which is not acting by momenta. Part I., Chap. V., art. 10, 11.

This surface may, according to the increase in degrees of velocity, be represented as more and more like a continuous and finite surface; it has however no real dimension, but may be called apparent, imaginary, and a mere surface. Part I., Chap. V., art. 13, 14.

When present it acts perpetually upon every finite, and by its presence acts upon the finites and disposes them into a certain motion, situation, and figure. Part I., Chap. V., art. 15.

Several actives of this kind may be fluent in one and the same space, without any concursion or conflict. Part I., Chap. V., art. 16.

Several of them together may adapt themselves to any angle and space; and taken collectively may represent any figure. One surface may apparently cross and cut another, and near [juxta] *one surface there may appear innumerable others crossing as it were over this one.* Part I., Chap. V., art. 13.

Several in one space can rarely be in contact with each other, unless they are in too considerable abundance; and even if they meet one another, they may nevertheless continue the same superficial gyration. Part I., Chap. V., art 18, 19.

Actives may occupy an exceedingly large space, and may likewise flow in an exceedingly small space, even within a surface consisting of finites. Part I., Chap. V., art. 20, 21.

Several together in one space possess a greater force of acting than a smaller number; or the force of the active space is increased and rendered the stronger according to the number of the actives. Part I., Chap. V., art. 22, and Chap. VII., art. 18.

The active of the second finite describes larger circles than the active of the first; and the active of the third finite circles still larger; consequently the actives of the fourth and fifth finite describe circles larger still. In like manner the active of the second finite does not flow with so great a velocity as the actives of the first; the active of the third finite flows with a velocity still less; and the actives of the fourth and fifth finite with a velocity less still. Part I., Chap. VII., art. 7.

The active of the second finite can be in the same space with the active of the first; and the active of the third can be in the same space with the active of the second; the active of the fourth in the same space with the active of the third; and the active of the fifth in the same space with the active of the fourth. Part I., Chap. VII., art. 8; also sec. 2, art. 6.

But the actives of the third and first finite cannot be simultaneously in one and the same space, without, (in consequence of the difference between their velocities, circles, and dimensions,) the circles and fluxions of the first active being altogether disturbed; so that this active would be completely pushed out of the space or become entirely absorbed. Thus, in consequence of the influx of the actives of the first finite, the actives of the third may ultimately lose their active force. Sec. 2, art. 7, 8. Consequently the actives of the fourth finite cannot be in the same place with those of the second and first; nor can the actives of the fifth be in the same place with those of the third, second, or first, without, (in consequence of the difference between the velocities, circles and dimensions,) the circles and fluxions of the actives of smaller degrees being put into a state of disturbance, and either the latter being themselves expelled from the space, or the actives of the larger degrees being occupied and absorbed by the influx of the smaller, and thus losing their activity.

The actives of the third, fourth, and fifth finite do not describe their circles or superficies round one centre or surface, but around various centres; that is to say, the derived actives run into surfaces or circles eccentric and not concentric. The apparent surface of the active seems by reason of this eccentricity another new surface proper to itself; and in consequence of the progression of the centre the actives are transferred into every imaginable point of their space. Part I., Chap. VII., art. 12, 13.

Actives cannot form anything contiguous, nor occupy any determinate place; they are thus destitute of all place and situation unless enclosed by finites or elementaries. Part I., Chap. VII., art. 14, 15.

They have nowhere in their space the relations of upward or downward. Consequently in the active space there is no such thing as weight; hence the largest space is as light as the smallest. Part I., Chap. VII., art. 15.

Actives cannot be said to resist but only to act. No number of actives constitutes an element or matter; actives, therefore, are not to be considered as elementary particles. Part I., Chap. VII., art. 16, 17.

The space which is filled with actives of the first and second finite together, acts more strongly than if it were filled with actives only of one kind. Part I., Chap. VII., art. 19. Consequently the actives of the fifth and fourth finite act more strongly than if the space were filled with only actives of the fifth finite.

4. Let us now come to the consideration of the actives of which we more particularly design to treat in this chapter, namely, those of the fourth and fifth finites. Let us consider more especially the active of the fifth finite, which is the cause and origin of our common atmospherical fire. With regard then to the active of the fifth finite, it follows from what we have stated, that *it is no other than the fifth finite itself set at liberty, or flowing in a space where it can run freely, like the*

foregoing actives, into eccentric circles and gyres; by means of which it may form as it were continual surfaces, and by its weight and impetus act upon whatsoever it meets. These fifth finites however constitute, for the greater part, the surfaces of the particles of air. The same result follows from the active of the fourth finite; for this active is nothing more than the fourth finite in a state of liberty, or sent into a space where, like the preceding actives, it can run freely, into eccentric circles and gyres, by means of which it may form as it were continual surfaces, and by its velocity and mass or weight act upon whatsoever it meets; but these fourth finites constitute, for a great part, the surfaces of the particles of ether, and occupy the central globe of the earth. As I have already treated of these subjects, it will be needless to dwell on them longer; but would observe only, that the actives of the fourth and fifth finite can operate upon the objects they meet, with greater weight than the actives of a smaller dimension. The fourth and fifth finites consist of a larger mass than the first, second, and third finites, and consequently act with a greater impetus.

5. *That the fifth finites cannot become active so long as they occupy the surfaces of the particles of air; and if by chance they should be set free from these surfaces, in consequence of the expansion of the aërial particles, they cannot become active without immediately illapsing into the surfaces of the other particles of air: and there, together with their like, performing a general motion, the same as the fourth finites do in the surface of the particles of ether.* Part I., Chap. VI., art. 14, 27, 28, 29, 30; Part III., Chap. V., art. 12.

6. *That the actives of the fifth finite cannot form any active space except among the particles of air, by which the space is enclosed and bounded on every side; consequently they can form no space among the particles of ether; still less among the particles of the more subtile elements, such as those of the first and second. That these actives cannot have any boundaries, but become immediately dissipated unless enclosed by aërial particles. That in like manner the actives of the fourth degree can form no space except among the particles of ether; (not among the particles of air, nor among the second and third elementary particles) and that otherwise they become immediately dissipated.* From

what we have already stated it appears, that actives cannot be enclosed in any space unless they are enclosed either by finites of larger dimension or by elementaries. Part I., Chap. VII., art. 14, 15. In the present case, however, there are no finites of larger dimension, and hence the actives cannot form any space within the connected circuit of the finites; this space can be formed only by the aërial particles upon which the actives can operate, and which can resist and confine and keep the actives within their limits only in the ratio of their own dimension. In the fifth finite the point is raised to the fifth power or degree, and hence it is considerable in mass; so that if the point be represented as 1, and if the first finite, for example, consist of 100 points, then the fifth finite will consist of 10,000,000,000 points; thus it is capable of displacing not only the first and second elementaries, but also the ethereal particles, from the volume of which it perceives during its gyration or fluxion but little renitency or resistance; and if there be no renitency, it cannot be resisted and enclosed by them, but ranges freely among them into all space. Thus can they form no active space, unless such parts are present as may enclose them, prevent their excursive motions, and confine them within their bounds. This can be done only among the aërial particles. Moreover, the surfaces which the active of the fifth finite describes in the course of its fluxion, almost equal in extent the particle of air, the surface of which is also occupied by similar actives. In this manner likewise do fourth finites become active within the volume of aërial particles.

7. *That the space formed by the actives of the fifth finite in the volume of the particles of air, cannot continue to subsist, unless it be continually supplied with a fresh quantity of actives; that is to say, unless the active space be continually supplied with fresh aliment. That otherwise the actives are immediately occupied by the first and second elementary particles, are converted into aërial particles, or illapse into the surfaces of the circumambient aërial particles, and so perish and become dissipated. That in like manner the space formed by the actives of the fourth finite in the volume of ethereal particles, cannot possibly subsist unless constantly supplied with fresh actives; that otherwise they become immediately occupied by the first elementaries, and are converted*

into ethereal particles; or else, illapsing into the surfaces of the circumambient ethereal particles, they perish and are dissipated. Unless new actives perpetually entered the space, those which are already in the space are either, according to the theory explained in our preceding chapter, convoluted by the first and second elementaries into new particles of air or ether, or else illapse into the surrounding particles of air and their surfaces, and thus either way perish and are dissipated. That they are convoluted by the first and second elementaries into new surfaces if they are in abundance, we have above shewn; but if they are not in abundance, they are, by reason of their eccentric fluxions and gyrations, immediately transferred into every imaginable point of their space, (Part I., Chap. VII., art. 12, 13,) hence immediately into the boundaries; that is to say, into the volume of aërial particles, where they are absorbed. They can everywhere enter into the interstices of the aërial particles, because these interstices are large; particularly when the aërial particles are in a state of expansion (a subject on which we shall treat in the sequel); they can also illapse into the surfaces of these particles, and together with their like perform a common motion in these surfaces. If new aërial particles arise, the quantity of the particles become increased, and together with this quantity the motion of the volume, as we find indicated by the phenomena of wind. If the actives illapse into the surfaces of the aërial particles, these surfaces may become larger, and consequently be in a more expanded state round about the space. If they become larger, their volume becomes lighter; hence the heavier particles tend in this direction, and hence the volume of the surrounding atmosphere tends as it were to a state of flame, more particularly if any part of the aërial particles which enter into the space be set free, and increase the number of actives; on which subject we shall speak in the sequel.

8. *That a large quantity of finites or of the actives of the fifth finite, enter into the compages and texture of mundane bodies, such as vegetable, sulphurous, oily, and other substances; from which new actives may perpetually emanate and germinate into the active space; that is to say, if the forementioned bodies are in the very space itself. That numerous aërial particles also may*

enter the compages and texture of these bodies, and that when these bodies are dissolved, these particles rush into active space. That aërial particles, in a state of separation from their volume and merged into active space, become immediately free; that all the fifth finites occupying their surface thus become actives; that in this manner fire may be abundantly fed by the air. That a similar law obtains with regard to the actives of the fourth finite, occupying the surface of the ethereal particles. There are many evidences to shew that fifth finites enter into the texture of terrestrial bodies, of those particularly which are of a finer and laxer compages, such as animal, vegetable, oily, and sulphurous substances; for these appear and grow only at the surface of the earth, that is to say, where the air is, on the confines of the mineral and elementary kingdoms; if the vegetable have no air to supply it, some part of its nutrition is seen to be wanting. Even from vegetables and plants it is very evident, not only that fifth finites but also that air itself has entered into their texture; for when submitted to the fire it escapes in large quantities in the form of flame, and presents the appearance of an expanded and flative aura. The same phenomena are presented by the process of distillation; for when vegetables are either cooked in a kettle or distilled, we find them swell and give out an immense quantity of steam and air; and the same phenomenon is presented if we dip either these or their juices into corrosive menstrua. We may arrive at the same conclusion also *a priori;* since the fifth finites are of such a nature, that the hard parts of vegetables may be compounded of them. On this subject however we shall treat more at large in our observations on the vegetable and mineral kingdoms. When therefore the textural connexions of these bodies are dissolved, the finites have room afforded them for rushing out; and if they escape in large quantities, it follows, that they become actives, and attempt at occupying space, so far as room is afforded them by the circumfluent air; and if the aërial particles themselves rush into this space, then in consequence of the great action of the actives, they not only become expanded, but experience a disruption of their surface, and thus the finites occupying the surface of these particles introduce themselves among the number of actives, and give increase and force to the space. In like manner, if the aërial particles, separated from the volume of their fellows, become merged into a space as active as we have described, they cannot but become most perfectly tense; and when agitated by so many actives, experience a disruption of their surface; for they cannot be protected or defended by any of the neighbouring particles; but being in the highest state of motion, abandon their surface to the destroying operation of the actives. For unless their surfaces be pressed upon all sides and be in equilibrium between the forces, the textural connexions of the surface cease with its equilibrium; because, as above stated, the aërial particle is pressed from within by the first and second elementaries, and from without not only by these elementaries, but by the ether, as also by the force of their own reciprocal incumbence. The same is true also even if there be no reciprocal incumbency and pressure. Indeed there would be none, should any particles separated from their volume float in the active space; in which case likewise there would be no equilibration of surface. Consequently the particles enclosed within must act according to their force and nature, and keep the surface in a state of tension according to the equilibrium of the reacting forces. This they do the more when they are urged by the actives of the space to their highest motion, in which case they are reduced to a state of still greater tension; hence they can now no longer defend themselves; and thus with the entire loss of equilibrium there is an entire loss of connexion in the parts constituting the surface. This will be still more evident in the sequel; I mean, that the active space acts upon bodies not only in a simple but in a multiplicate ratio. From the foregoing observations it follows, that *aërial particles in a contiguous volume with others, or those in the boundaries of the active space, cannot be set free, or the parts of their surface cannot become active, unless they are separated from the volume of their particlès and enter into spaces;* which is the reason that flame is so copiously fed by the air, and its power and heat so considerably increased. In these processes we behold a type of nature ever repairing and renewing herself: like the phœnix, she rises from her ashes; as oft as she dies she comes again into life; awakens from her funeral pile to a new resurrection. For the air undergoes a process of dissolution [*perit interitque*] when entering into the compages of the parts of vegetables, and if these vegetables be submitted to the fire, the air returns again to its former state; in like manner if vegetables boiled or rotting undergo fermentation, so that the more intimate connexions of the compages be dissolved, the air immediately regains the proportion abstracted, or the earth restores that which it had borrowed. Thus are the operations of nature carried on in a perpetual circle. In death she beholds life; in her funeral pile, her resurrection.

9. *That the particles of air nearest the active space are in the highest degree of motion, and consequently in the highest and most rigid state of expansion. That such as are farther from the space are in a less degree of motion, also in a less degree of expansion and tension, and this according to their distance from the active space. That in like manner the active space cannot subsist unless the aërial particles be expanded according to their distance from it; that is to say, unless there be formed around the space a sphere of particles gradually less and less expanded and mobile. That a similar law obtains with regard to the ether round a space consisting of actives of the fourth finite.* In Chapters V. and VII. of the present Part, we have shewn that both ethereal and aërial particles are, during their greatest motion, most highly and rigidly expanded. In the present case the aërial particles are expanded from a threefold cause; they are also agitated by their actives and excited to motion, and when thus excited the enclosed elementaries stretch the surface; the nearer also the aërial particles are to the space in which there are only the first and second elementaries, perhaps also some ethereal particles, the less are they in a state of contiguity so as to be capable of being pressed in every direction by their mutual incumbency. A new supply of finites also takes possession of their surface, by means of which they can become more expanded; hence near the active or igneous space they are in every respect more expanded than they are at a distance from it. From the equilibration of the parts in motion, it is evident however, that the active space cannot subsist unless there be formed a sphere of particles expanded more or less according to the distance from the space. One elementary particle is not moveable by itself, for in moving it we cannot but move also the

next in proximity, and the next again to this, and so on throughout the distance; for all the particles are in one contiguous expanse, and the motion of the parts is the motion of the whole volume; hence the motion of one or more of the parts is extended into those which are proximate, a motion which cannot decrease except according to the distance, and which must become more or less according as the motion of the parts is more or less rapid and local. The same is the case with regard to a volume of the aërial parts encircling its igneous space. By means of this sphere of aërial parts surrounding the igneous space, not only is the equilibrium in the air preserved, but also the space together with its actives is enabled to subsist; for the aërial particles are thus endowed with the greatest aptitude to receive the assailing impetuous force of the actives, and there is a certain similarity of action in the aërial particles and the actives of the space.

10. *That the aërial particles themselves, when excited to the highest degree of motion by means of the actives of their space, give rise to a something similar to actives; that they produce likewise a something igneous and warm; that they also dissolve the connexions of certain parts. Thus that in their state of expansion and mobility, the aërial particles resemble a kind of actives, although in one respect not so; namely, they do not excite the volume of ethereal particles into such a motion as to diffuse any light.* Since not only the aërial but also the ethereal particles when expanded are thrown into a state of most intense central motion, it follows that these particles produce in their place an effect almost similar to that which actives produce in theirs; the only difference is, that the actives act by local motion and at every angle. They are present throughout all space in the ratio of their eccentric and excursive motion, and wherever they meet with an obstacle they turn it about, they solicit it, and operate with a degree of impetus and weight upon its smaller structural connexions. The ethereal and aërial particles, when in their central motion, act also upon structural connexions similar to their own, and consequently produce a species of warmth or fire. Heat is thus a most intense central motion of the parts of air or ether; and the mechanism of the operation and dissolution of these parts I shall explain at large, when we

have first ascertained the connexions and compages of these parts from our theory of the mineral and vegetable kingdoms. The origin of heat of this kind is principally in the actives which are capable of putting the ether and air into motion, and also of so modifying the ethereal volume as to cause it to diffuse light, or to cause its contiguous expanse so to act at a distance upon this motion or effort as to reflect itself at every angle from any intervening object, and thus to render it visible to our organs.

11. *That ethereal particles can be in the same space with the actives of the fifth finite; but that when they are in this space they are excited to a most intense motion; and consequently in this state of motion are in a high degree of expansion and rigidity. That ethereal particles thus contribute in a signal manner to the degree and augmentation of heat. That the actives of the fifth finite may in their space urge an ethereal volume into such a high degree of motion, that this volume may give rise to modifications which have the appearance of light. That the ethereal particles also interiorly in this space may be dissolved, and the space, thus increased by the actives of the fourth finite, be rendered stronger and larger. That finally the ethereal particles may at length in some measure be exterminated, as the active space increases in force and extent.* That the ether can be in the same space with the actives of the fifth finite, and that the actives may nevertheless continue to perform their circles and gyrations, follows principally from the dimensions of the two. The finites constituting the surface of the ether are of the fourth genus, and in these the point is raised to the fourth degree and power; so that if we consider the point as one, there are then in the fourth finite 100,000,000 points, as we find by multiplying every dimension by 100. The fifth finite however, in which the point is raised to the fifth power, possesses a mass 100 times larger, or one consisting of 10,000,000,000 points, being to the former in the ratio of 100 to 1. If therefore every particle of ether in the surface consisted of a hundred finites, the particle would not much exceed in mass the fifth finite rendered active, and thus may this active perform its gyres within an ethereal volume, although not without experiencing some renitency. Fourth finites, however, when rendered active, remove from them the ether according to the principles we have laid down, and cannot

perform their gyres within its volume as we have above stated. Inasmuch however as the actives of the fifth finite cannot but whirl about their volumes among the particles of ether, by acting upon, soliciting them, and urging them hither and thither, in order to form a space to themselves; and inasmuch as these particles, being most highly mobile, readily yield to actives thus in motion, it follows that the ethereal particles cannot but be, according to our theory, when in the highest state of motion, in a state of the tensest expansion, and when expanded occasion [*intendant*] a degree of heat and fire, particularly if there be any connexions of parts upon which these particles can operate in their own way; that is to say, both by a central motion and by expansion. The ethereal particles therefore in this state of motion and expansion cannot but, to a considerable distance, dispose the volume or contiguous expanse of their particles into a certain state of motion, so that the ether may impinge upon the parts it meets and which are variously configurated, and by reflecting and refracting itself present various modifications to the organs of vision, which also contribute their own share in producing the effect. If the number of actives increase and the space be rendered still more strongly active, it follows that the ethereal particles possessing a less force of resistance are compelled both in place and space to give way; they also partially experience a disruption, particularly if they are very rare and begin to be separated from their contiguous expanse. If they experience a disruption, then not only a larger number of actives enter into the space, but also a stronger force (Part I., Chap. VII., art 19); for the actives of the fourth finite can operate upon their own smaller connexions both in virtue of their smaller mass and their greater velocity, as well also as the actives of the fifth finite.

12. *That the first and second elementaries can be in the same space with the actives of the fifth finite; and do not in any manner disturb their circles and gyrations, but yield to them just as the atmosphere yields to any weight, gyrating or revolving within its volume.* For the first and second elementaries are of a smaller dimension and are more yielding and elastic, as being those in which is latent the primitive elementary yieldance and elasticity; hence there is nothing to prevent these actives which are larger

in mass from being fluent among them. The actives of the fifth finite are thus in a free state when introduced into the space where only the first and second elementaries are fluent. For in the surface of the first elementary there are second finites which may be in their ratio to fifth finites as 1 to 1,000,000. In the surface of the second elementary there are third finites, which in regard to their mass are in the ratio to fifth finites as 1 to 10,000, or even still more. For the ratio of the point to the first finite we have assumed for example's sake as $\frac{1}{100}$, whereas it may be $\frac{1}{1000}$.

13. *That the force of the active space increases according to the increased abundance or number of the actives in the same space, and according to the addition of the actives of the fourth finite to the number of the other antecedent finites.* On this subject the reader is referred to Part I., Chap. V., art. 22; Chap. VII., art. 18, 19.

14. *That the space consisting of the actives of the fifth finite has no weight except what is given it by the volume of first and second ethereal elementary particles forming the contiguous extense* [contiguum] *in this space. That this space moreover has no determinate situation except that which is given to it, or is determined by the enclosed ethereal and elementary particles, as also by the aërial particles, which are circumfluent and rendered lighter by their expansion.* On this subject see Part I., Chap. VII., art. 14, 15. There may in the meantime be in this space an ethereal volume which has a determinate situation relatively to the particles of its own nature, which are circumfluent in the same contiguous space; the space therefore may in some measure be affected according to the situation of the ether, as also according to the situation of the elements of the first and second finite, more particularly according to the circumambient air enclosing the space itself.

15. *That the actives of the fifth finite operate by their degrees and impetus upon the various objects they meet, and dissolve their connexions. That the ethereal particles also, which are in a state of intense motion, operate upon them by their central gyrations and their activity thence resulting; as also by means of their expansion. That the space itself, too, by reason of its lightness acts upon the connexions of the harder bodies, and dissolves them by*

reason of the equilibrium and ratio of its pressure on both sides; that is to say, both without and within the compages of the bodies. That numerous causes may thus assist in the resolution of bodies by fire in an active space. For the actives of the fifth finite act by weight and impetus, as we have sufficiently shewn above; for there are numerous connectives of bodies, some of a more subtile, some of a crasser nature, which cannot be dissolved by actives of the same kind; crasser connectives are dissolved by actives which are crasser; and more subtile connectives, by actives which are more subtile; hence in an igneous space the solution of the parts even to a degree of fluor, requires the weight and impetus not only of actives of the fifth finite but also of the fourth. What that is which is effected by actives we have explained in Part I., Chap. V., art. 10, 11. Moreover ethereal particles in their state of mobility and expansion operate upon their connexions, conjointly with the actives, both by their continual central volutions without and within their compages, and by their levity as acquired by the expansion of the ether and the extermination of the air. For the ethereal particles which are enclosed in bodies exercise a tendency to the same degree of expansion, inasmuch as they tend to a state of equilibrium; hence by reason both of the tension and motion of these particles, the compages which itself is tense becomes disrupted, and opens a passage for the enclosed particles freely to escape and fill the space with fresh actives from the fifth finite; just as air when enclosed in a bladder or jar and distended by heat, bursts through the walls of its confinement, and rushes with a blast through the fracture it has made. Numerous causes therefore occur before a body completely dissolved passes into a state of fluidity, or becomes converted into smoke, ashes, cinders, or fluor, and before the parts which cohere by the more subtile junctures, being divided become finally separated. *Now inasmuch as the active space cannot subsist except by means of new actives, which perpetually enter into the space and so constitute it; it follows, that it cannot subsist unless it be always replete with parts of the same kind, and which the forementioned actives supply by their dissolution; so that the space must thus be crowded with sulphurous, oily, saline, vegetative, and other kinds of particles; for which reason the space can extend itself no further* *than the tide of these particles from which the actives come. Hence also it follows that this igneous space may be rendered in its action stronger and weaker, according as the parts floating in it supply a smaller or larger quantity of these actives.* Not to mention other circumstances which are rather matters of detail than forming a part of the general law.

16. *That the space consisting solely of actives of the fourth finite and enclosed by the ethereal volume, can transmeate the atmosphere with a perfectly free current; that it may as it were cleave through and penetrate even the hardest bodies; that it may in its passage break and dissolve their more subtile connexions, and give rise to more phenomena than the space which is formed by the actives of the fifth finite.* For actives of the fourth finite can be enclosed only by a volume of ethereal particles, and consequently a space of this kind freely permeates the atmosphere and the interstices between its particles (for the air cannot retard its passage, because it is of larger dimension), and the moment it touches a particle of the air, it breaks and dissolves its connexion: it does the same with other corpuscles and effluvia floating in the atmosphere, as also with whatever larger and harder bodies it meets; moreover the force of the space is increased and becomes more intense by the solution of the ethereal particles separated from its volume. Hence it is that this kind of fire is called elementary, because being generated in the form of lightning in the superior regions it tends to the inferior and carries with it a matter having a loose consistence of fourth finites; from which, as from a most subtile sulphurous substance, new actives and aliment pass out perpetually into the space. To describe more particularly the nature of this celestial fire and its prodigious effects, would be undertaking a task too prolix for the reader, although we might deduce them all in regular sequence from our principles. These are the fires that, according to the ancients, Jupiter grasped in his right hand and flashed out of his cavernous clouds; these are they which almost without contaction penetrate the looser compages of bodies and leave them intact, while they break through and divide the finer and less obvious to the eye. Thus in the animal body, they lay open and loosen the hard and bony parts, but not the fibrous and

fleshy; the subtile connectives by which the soul unites itself to the body they more particularly lay open, widening all the channels and passages leading to the soul, and through which as it were the soul exhales itself. The reason of the phenomena produced by this kind of fire every one may learn for himself from the principles we have above explained.

17. *That of these fourth finites it is that the central globe of the earth consists; but that they cannot make any eruption and actuate themselves without being immediately occupied by the first elementaries, and converted into ethereal particles, according to the theory above laid down. That if however there were a passage leading from the centre sufficiently open for the forementioned finites to escape through it, an active space would be formed by that part, at our present distance from the sun; and that when formed it might continue to subsist so long as fresh finites constantly emanated and as it were germinated into the space; but that by means of this space the sphere of the ether would considerably enlarge itself, and the earth would lose that equilibrium which it now maintains at its present distance from the sun and in its present vortex; and consequently that it would undergo some signal change not only in regard to its situation and to the circle it describes in the vortex, but also in regard to its polar situation and axillary motion.* I wish to mention this only as a corollary to our preceding propositions. It is possible that some such destiny may await our earth; and if so, it is one of which we cannot have any foreknowledge; neither can any one predict it, unless by indulging in such conjectures as would be calculated rather to excite a smile than to be worthy of our graver thoughts.

18. By way of appendix we may here observe with regard to the actives of the sixth and seventh finite, that even these are possible, particularly since nature is enabled to ascend to higher degrees and powers of finiting and actuating itself. Let us suppose therefore the existence of finites or actives of the sixth finite, then from our principles it follows that they cannot be enclosed by the atmosphere, consequently that no space can be formed by them within the limits of any portion of our atmosphere, but that possibly they may be enclosed within a space by a volume of aqueous vapors. A space formed by the actives

of the sixth finite would powerfully move the air, expand its particles, and thus induce a certain kind of heat, as in the case of the actives of the fifth finite moving the ether.

The seventh finites however, or the actives thence resulting, appear to be capable of forming no space within the elementary parts of our world, and could they exist conglomerated in any place, would discover themselves by some kind of noise in the atmosphere. They could never dissolve the connexions of cohering parts, but would occasion only a certain degree of contusion, and were any intelligent person present who knew how to connect them together so as to form a space and confine them within fixed limits, they would assume and represent all manner of Protean and Vertumnian figures and images. See Part I., Chap. V., art. 17. Let us however leave subjects of this kind, and pass on to those series of things in the world which have a real existence.

CHAPTER IX.

ON WATER OR THE PURELY MATERIAL FINITE.

Hitherto we have been pursuing the course of the earth through the vortical solar region, and have seen how at a certain distance from the place of its nativity it became surrounded with an atmosphere. We may now contemplate the earth as still pursuing its course, as not having yet arrived at its final and destined orbit, but as constantly increasing its radial distance from the sun, from which it is receding diurnally and gradually. Every year the earth describes around its parent a brief gyration; every morning it salutes its parent anew, and every evening bids him farewell, for it is constantly measuring out days by a revolution upon its axis; thus is it perpetually meting out time by annual and diurnal revolutions. Its course being spiral, it is yearly and daily receding from the centre of its orbit; for by reason of its centrifugal force, it is ever hastening to its ultimate orbit and fixed boundary; on which subject we shall treat in the following chapter. Now as we are accompanying its course with a view to observe the changes through which it passes, let us mark in what manner it surrounds itself with water, and afterwards with a fertile crust of most varied aspect and abounding with entities of the most diversified kinds; a crust which in a state of resolution not only yields seeds, but unfolds them into different kinds of fruits and plants: let us mark also how, after it has adorned its surface with the beauties of the garden and the field, man is finally introduced, as into some spacious apartment enriched with magnificent furniture. As yet the surface of the earth is naked, being surrounded only with ether and air; nor indeed can it receive any covering in closer proximity with its surface until it has travelled to a greater distance from the sun, and until by means of successive gradations and vicissitudes it is enabled to produce around itself various series, both successively and simultaneously. We now come to the subject of water. It follows in a connected sequence from our principles,

1. *That a particle of water is similar to a compressed particle of air, according to* Fig. 110 (p. 294), *in which there remains nothing elementary, yielding, and elastic, but a something hard, consisting of contiguous spherules formed within another larger spherule, according to the theory propounded in* Part III., Chap. V., art. 14, 19; Chap. VII., art. 11. *That the particle of water is not a finite like one of the preceding finites, namely, capable of actuating itself, but is one which is purely material. That water consequently is not an elementary particle.* In order that the connexion and series of things successively arising, may be made the more evident and be the more clearly explained, we shall begin with the figure of the particle, from which it will be evident that it had its origin either simultaneously or successively with the air; of which subject we shall soon treat. At present we shall follow the successive steps of the series, and shew how a particle of water is perfectly similar to a particle of air, or indeed is the same with a particle of air highly compressed; and inasmuch as in this particle there is nothing elastic and yielding, for the enclosed elementaries are consumed in compounding the spherule, (which in consequence of being interiorly deprived of its elastic elementary volume cannot be farther expanded, much less compressed, or be made to yield or to flow among the neighbouring particles in virtue of its own proper mobility and so to remain, in every state of motion, similar and perpetually fluid,) and the consequence is, that the spherule or particle cannot be called elementary.

With regard then to the origin of water, we may observe, that water seems to have originated in the same manner as the aërial particles, but at an early period [*in principio*], and before the ether had attained its present altitude or quantity; whence the newly arising aërial particles were then larger, particularly in the vicinity of the sun, where all the parts, which were circumfluous and occupied the surface, were in a state of most intense motion and heat. At a distance, however, while the ether was yet increasing in abundance, and in like manner the air, it seems impossible but that the particles of air which first arose with extremely large dimensions from the circumambient ether, must become more and more pressed with a higher column of similar particles until they arrive at their highest state of pressure, so as to lose their elementary nature and become converted into hard and resisting bodies. At a still greater distance from the sun, however, when the air was perpetually arising in the atmosphere of the enlarged ethereal regions, the aërial particle, it seems, could no longer continue of the same size; because coming into the highest state of compression so as to be entirely occupied by spherules formed within, in the formation of these the first and second enclosed elementaries are consumed, so that scarcely any remain to restore the elasticity of the particle and to expand it further. Such is the origin of aqueous particles, deduced immediately from our first principles, so that they appear to be in the same series with those of air; and inasmuch as the origin of each is thus one and the same, the reader is referred, for our remaining observations on this subject, to our theory of the origin of air. The only difference between the two is, that in consequence of its larger surface, the aqueous particle at the surface of the earth is pressed by the increasing quantity of ether, and by the accession of air which perpetually enters into it, into a state of equilibrium with the other particles; consequently so considerable a portion of its extremely large surface is pressed inwards, as to be received by the enclosed elementaries and formed into new spherules, which gradually throng the particle and render it hard and resisting; thus urging and keeping it, in the ratio of its weight, near the surface of the earth. The figure of the particle may be seen in Fig. 110 (p. 294), H, H, is the particle; and its parts, *n, n, n, n, n.* A shoreless ocean thus envelopes the earth, which presents the aspect of one universal waste of water.

2. *That particles of water, or finites of this kind, cannot move one among the other like elementaries, unless there be interfluent elementaries to carry these particles with them, and thus*

set them in motion. That the particles of water thus owe their motion and fluidity entirely to the interfluent ether. That aqueous particles are the more mobile and fluid, in proportion as the circumfluent ethereal particles are the more mobile, extended, and rigid; and the less mobile and fluid in proportion as the circumfluent ethereal particles are the less mobile, extended, and rigid, but as it were flaccid. That in proportion to the want of mobility and tension in the ethereal particles, the aqueous particles are torpid and languid, uniting and concreting into a hard mass. That finites of this kind or aqueous particles owe their fluidity or mobility to the interfluent ether, which in its own nature is mobile because it is elementary, is evident *a priori*, or from the principles already laid down; for the particles of water do not possess an even [*levi*] and uniform surface, but one which commonly coheres in a state of contact with those which are in proximity with it; neither do they possess a yielding elastic surface; for which reason they cannot reciprocally act upon each other by their force of elasticity and yieldance, and thus become similar and uniform in every state of motion and compression; nor can one particle apply itself to another in the manner of elementaries, which cannot become reciprocally fixed and colligated; but still in whatever motion they may be, they are, solely by reason of their change in dimension, (their figure being in other respects exactly preserved,) enabled to maintain a mobility. For when the ether is in its most mobile and rigid state, that is to say, when its temperature is warmest, it renders the water most highly mobile, and makes it undulate and boil from the top to the bottom. The ether moreover circulates itself in water, forms itself into vapours, and under the appearance of air continually seeks the surface, and ejects itself in the same manner as when steam carries a body upwards. Still in a perfectly quiet and serene state of the ether, when its particles from being flaccid as it were, are unable to move the aqueous particles from one place to another or to keep them separate, it is impossible but that the aqueous particles should become confluent and attach themselves one to the other; the ether itself partly escaping, inwardly glomerating partly into vapour, partly into larger particles, and by the solution of its flaccid and highly yielding surfaces, inclosing itself like air and variously occupying the spaces within, from which it is unable to escape as long as it is between its own larger or else congealed vaporous surfaces of the water. This is evident *a posteriori,* because when there is no motion between the ethereal particles, the aqueous particles coalesce into a certain hard and material mass, from which they cannot be liberated except by the ether being put into motion and a state of rigidity. The essentials therefore, and numerous elementary qualities which we have observed in the wave and current of our finites, we must not attribute to their own nature or virtue, but to the interfluent element; as when for instance we have observed, that water exercises a pressure proportioned to its altitude, proportioned also to the area exposed to the column or altitude; that this pressure is exercised equally in all directions; that the particles are put into modulated states and circular undulations; that these undulations may be formed within the sphere of another undulation; not to mention numerous other particulars which we may see verified not only in other fluids, but also in every liquid and every volume of every hard and liquefied body. It appears then that we cannot consider the aqueous particle as any other than a certain hard body rendered fluid by an extremely small degree of heat; for some hard bodies there are which become liquid by a smaller, some by a larger and more intense degree of heat: water commonly yields to the smallest degree, which softens its rigidity and causes it to flow as a liquid.

3. *That the ethereal particles are capable of permeating the interstices of water; but not the aërial, in consequence of their difference in dimension. That the aërial particles are therefore contiguous with the aqueous as to surface, and press upon them in proportion to the altitude or weight of their volume.* From our theory of the origin of water, it is evident, that the aërial particles are larger than the aqueous, and consequently cannot enter into the interstices between the latter, without forming spaces by collecting into volume; hence it follows, in conformity with common experience, that the aërial particles are contiguous with the aqueous only as to the surface, and press upon them in a degree proportioned to their altitude or weight of volume.

4. Many other circumstances remain to be noticed with regard to water; but inasmuch as its particles are not elementary,

nor constitute any portion of the elementary kingdom, the proper place for noticing its phenomena will be where, with the divine permission, we come to treat of minerals; for the aqueous volume is perfectly similar to that of a mineral of any kind melted into a volume or liquid. Innumerable therefore would be our remarks on the subject of water were we to enter into all its phenomena. We should have to shew, for instance, in what manner and by what causes the connexions of its particles could be resolved; in what manner after the dissolution the enclosed spherules occupied the interstices between other and aqueous particles; in what manner were hence originated new terrestrial and saline parts; what were the figures of these parts, and their motions between the aqueous particles; in what manner these particles convey them through the fibres, stems, and pores of vegetables; how it is they dispose them into the vegetable form; how again they carry with them the superfluous parts in the vegetable into the external atmosphere; how it is that water hardens into ice and its vapour into snow; how figures are hence formed similar to the vegetable, together with many other particulars pertaining to the material kingdom of nature, both vegetable and animal.

CHAPTER X.

ON AQUEOUS VAPOUR OR THE FIFTH ELEMENT OF THE WORLD.

We now come to the last product of the elements of our world, namely, vapour formed from water; a product, which although the last, is yet as an elementary the first perceptible to sight and touch; for if we take a side view of the surface of warm water, we may see subtile vapours arising in a round form, and the surface of the water expending itself, and passing in strata gradually into a new kind of elementary product. Thus in forming her elements nature terminates where the senses begin; being visible only in her last and ultimate limits, and ending as it were where the knowledge of the senses first commences; rendering herself visible to human eye in order that man may not be ignorant of her qualities. The reason of this is, that the material perceives only by means of the elementary; for perception is effected only by means of motion in the elements. Our sensual organs are material and can perceive nothing except through the medium of the elements; hence they perceive effects but not causes; the cause acts in order that the effects may be perceived; hence no elementary can be perceived but the last, which does not operate any longer upon any of our organs.

By this first visible elementary is confirmed the theory of our principles; for even the senses now perceive certain particles rising anew from the surface of warm water and flying upwards in aggregations into the atmosphere; they see that the origin of these particles is near the surface and not in the middle of the volume; that water suffers itself to be carried off in obedience to the motion of the elementary parts; that the particles thus rising are of a perfectly round form, except when in their flight to the superior regions they seem to assume more of the oval; that the ether set in motion by the sun or fire glomerates and rolls them into these forms and occupies the space within, the watery particles being circumfused into the appearance of a surface or expanse, in the same manner as we have explained with regard to the origin of ether and the air at the surface of the yet unfurnished earth; where in like manner the parts next to its surface were raised by the first elementaries into the ether and at the same time by the second elementaries into the air, the elements occupying the interiors of the particles and the finites their surface. Thus nature acts in small things in like manner as she does in large ones; in the case of first and second elementaries, in like manner as in that of the third and fourth elementaries; in the case of the fourth and fifth finites, in a like manner as in those of larger dimension, that is to say, in a like manner when air and ether are generated as when vapour is generated. Again, vapour when generated, can subsist among the circumfluent mobile and elementary particles, and preserve its sphericity in the same way as ether and air among their elementaries; this vapour can be expanded and compressed in like manner as the ether and air; in a word, in vapour we may contemplate and perceive with the eye the whole mechanism and geometry of our elementaries. The circumstance of vapour subsisting only for a few hours, days or weeks, arises from the changes to which the ether and air are subject; for in the vaporous particle the ether is inclosed, and hence it must undergo the same change with the ether; the air also is fluent around it, and hence it must undergo the same change with the air; and inasmuch as both the air and the ether are in their higher regions dissimilar to themselves according to the momenta of their distances from the earth, it follows that the vapour which is carried to the higher regions is under the same regimen as the elements, which press partly from within and partly from without, or which constitute the particle itself. For this reason it is that I have observed that we now come to the ultimate of elementary nature and to the first object of our senses, and thus also that our principles proceed by derivation from the first invisible and as yet ungeometrical simple, to the ultimate of the elementary kingdom, or the first visible product, the nature of which I now come briefly to explain.

1. *That vapour is formed on the surface of water, and from the motion of the interfluent ethereal particles. That vapour when formed encloses within itself a small volume of ether; and externally is pressed both by the ether and air. That the surface is thus equilibrated by forces flowing without and within; and preserves its spherical form under every degree of compression.* Of the formation of vapour near the surface of the water we have just spoken, and in consequence of the parallelism which exists between the two, we may transfer to our theory of vapour what we have already diffusely stated in our theory of elementary particles; as for instance, that they can originate only at the surface or confine of the extrafluent elementaries, where they are most highly mobile; can separate from others, to associate with the most highly mobile and together with these be put into motion, and consequently be convolved into a superficial expanse, as is abundantly evident both from our principles and from experiment; for within their volume they cannot unfold themselves, since the proximate particles prevent them, and resist in the ratio of the column. Inasmuch therefore as ethereal particles are fluent in the interstices of water, they are hence rendered tenser and stronger, and, together with the others which externally press the surface of the water tending to the same state of expansion or equilibrium, must necessarily be enabled to dislodge the superficial particles, raise them to a certain extent, and together with the rest combine to form an expanse: just as we see represented on a larger scale when water is placed over the fire, in which case multitudes of these particles project themselves from the bottom and escape in bubbles. Thus it is that aqueous particles become enclosed by the ethereal, and that a particle is formed whose internal space is occupied by the ether; which consequently according to its nature presses in every direction upon the concave part of the aqueous expanse, while the ether also together with the air presses upon its convex. Thus do these two elements occupy the intermediate surface, and equilibrate it in a state of compression in

the same manner as in a state of expansion; they always preserve it in a convex or similarly spherical state, in the same way as we have above observed on the subject of the elementaries.

2. *That vapour may be compressed and dilated; that it possesses a yielding and elastic surface; but owes all its elasticity to the enclosed ether, and the ether to its enclosed first elementaries. That vapour is hence a particle not fully yielding and elastic, consequently not perfectly elementary, but similar to an elementary, or endowed with elementary properties* [elementata]. Inasmuch as its space is now occupied within by ethereal particles, and these according to our theory owe their elasticity to the first enclosed elementaries, it follows that vapour owes its elasticity and yieldance of surface solely to the enclosed ethereal particles. And inasmuch as in the first elementaries the elasticity is primitive, in the ether it is derivative, and in vapour it is derivative from the ether, it follows that vapour or steam is distant some degrees from the source of genuine elasticity, and admits into itself no other elasticity than that of the enclosed ether. Vapour may thus remain in its state of expansion, although pressed around by contiguous particles and by weight, provided the ether be in its state of rigid expansion; the vapour thus pressed by contiguous particles may collapse into itself and be compressed, provided the ether be not in a state of expansion or motion. It may thus undergo a variety of states of expansion and compression, and exhibit phenomena according to the operation of the enclosed and circumfluent elements. Although the vapour therefore possesses an elastic surface, it does not always yield to the compressing force, unless the enclosed ether itself also yields. It is not consequently under its own control, although it possesses in potency the force and mechanism of elasticity; hence it is not truly elementary, but may be said to be endowed only with elementary properties, or in other words, to be elementated. We have always presumed the vaporous expanse to be contiguous. From these observations it follows, that *the surface of the vaporous particle may be variously multiplied; that in its state of compression it consists of numerous duplicatures, series, and expanses; that in its state of expansion it consists of a smaller*

number, and thus that it may be expanded and compressed according to the state of the enclosed ether and surrounding air. On this subject the reader is referred to the theory of elementary particles explained in Part I., and also in the present Part.

3. *That a large volume of vapour may arise from a small volume of water, and that this volume may become more and more expanded by the application of heat; indeed that it may be expanded with so great a degree of force and tension, that large weights may be lifted up, and walls of iron and brass be burst asunder.* Chemists are well aware from experience that a small volume of water may originate a large volume of vapour, and that a contiguous vaporous expanse may force its way through teguments of brass and iron; moreover the workmen at founderies and smelting-houses have frequent opportunities of seeing heavy weights elevated by steam; for if small drops of water happen to have been enclosed in the running liquid of brass or iron, or are so situated underneath it as to be unable to escape without passing through, the whole mass of fluid will distend and bubble, and project itself upward, and scatter its burning fragments through the edifice. If the connexions of the particles of the fluid metal with which the water is surrounded be unyielding, as we sometimes observe when scoriæ are flung into water, the water will nevertheless disrupt the bonds of connexion, and hurl the parts as from a sling with a degree of violence and a loud explosion. Let us however revert to principles; for were I copiously to illustrate them with experimental facts, I should have to fill volumes. Every specific element when submitted to examination, requires its own specific volume. Similar is the case with our present theory of vapour. Still however I would also shew that vaporous particles, when forming a contiguous expanse, possess the same force and quality as air and other elements: vapour swells for instance on the application of heat, and distends any coercive bonds just as air distends bladders. Hence it is evident that every particle of vapour is similar to an elementary, which is capable of being expanded and compressed, of flowing in contiguity with its proximate particles, and of subsisting in the highest degree of motion; neither can it be forced out of its spherical form by any weight or in-

cumbent mass: it may likewise exercise a pressure equally in all directions; in a word, it is perfectly similar to its progenitors, the air and ether. We are thus forbidden to doubt that the forementioned elementaries are acted upon by the same mechanism as the new particle endowed with elementary properties. From its parallelism therefore with the elements it follows, that *any particles of vapour forming a contiguous expanse are capable of the highest degree of expansion; that the expansion may gradually continue to increase if a constant stream of water be furnished from which new particles of vapour may not only arise and pass into the contiguous expanse, but be in a state of transflux from one vapour to another in one continuous current, ascending from the bottom to the top, and thus may afford room and sufficient means for expanding themselves still further. And if any portion of these particles burst in consequence of too great an expansion, the diffluent water hence arising and illapsing into the surfaces of the neighbouring particles, always furnishes them with fresh means for a further expansion.*

4. *That particles of vapour differ from bubbles of water in this respect, that interiorly the former contain only ether, while bubbles contain both ether and air.* In these particles of vapour we may see a still further product of elementary nature; since not only the ether but also the air encloses itself in an aqueous surface. As these phenomena are perceptible to the eye I need not any longer dwell on the subject.

5. Finally, before leaving our theory of elementaries, I would wish to explain in a few words the connexion extending, according to our principles, from the first simple down to the aqueous bubble. I would observe then that *in every bubble of water is contained all that had previously existed from the first simple; every genus of finites, actives, and elementaries, of which we have treated in the course of our present work; so that in a small bubble is latent the whole of our visible and invisible world.* We have thus the macrocosm in the microcosm; the world in a particle; the whole of our *Principia* in a nutshell. In the minutest things we have the same laws of nature as in the largest; the same in a whole as in a part; in the smallest minutia we behold the principles of nature's mightiest operations. For we see in

an aqueous bubble the fifth element or vapour, the aqueous surface, for instance, with enclosed ether; we have also air or the fourth element of the world enclosed, as we learn from the preceding article; around the air we have the ether, or the third element around the ether, and in every particle of the air we have the second element; around the second elementaries, as also in the air and the ether, we have the first element; thus we have all the elements both without and within the compages and surface of the other, and these all again enclosed within a bubble of water. The case is similar with regard to the finites; the simple or the point is latent in the composition of the first finite; the first finite in the composition of the second; the second in the composition of the third, and in the surface of the first elementary particle; the third finite in the composition of the fourth, as also in the surface of the second elementary particle; the fourth finite in the composition of the fifth, and in the surface of the ethereal particle; the fifth finite in the surface of the particle of air; the material finite or water in the surface of the bubble; thus have all our finites made their entry into a bubble of water in regular order. Again, in regard to the actives, the active of the first finite is latent in the first as also in the second elementary particle; the active of the second finite in the second elementary particle; the actives of the third, fourth, and fifth finite, in the surface of the second elementary particle, the ether, and the air. These actives also are one and the same with finites, which, in a free state, according to our theory, exist as actives.

The nature of the connexion of the elements one with the other is evident from this; that the first element surrounds and presses the second; the second surrounds and presses the third; the third surrounds and presses the fourth; the fourth surrounds and presses the fifth; thus do all the elements from the first to the last form together one contiguous expanse; one therefore maintains a relation to another, and thus do ends connect themselves by intermediates; the last with the intermediate, the intermediate with the simple; or what amounts to the same, the ultimate end is connected with the simple; and these are the more perfectly connected in proportion as the connecting elementary parts are in their natural state of motion and freedom.

Whatever befalls one is immediately communicated from it through the intermediates to the ultimate. The smallest tremulation in any part of the surface of our bubble communicates immediately an entire tremulation to the surface of enclosed air; the tremulation of the air communicates a tremulation to the ether; the undulation of the ether communicates a certain local motion to the second element; this motion of the second element impresses a considerable local motion upon the first element; consequently the least motion in a crasser element causes a considerable motion in the finest, and thus it is that motion is spread from one extremity to another by reason of the general contiguity of all the elements, and the special contiguity of each in itself. Thus does the thread of our principles extend from the simple to the ultimate without a single broken link; and thus may we see how from one and the same force and cause all things derive their origin.

CHAPTER XI.

ON THE VORTEX SURROUNDING THE EARTH, AND THE EARTH'S PROGRESSION FROM THE SUN TO THE CIRCLE OF ITS ORBIT.

Before proceeding to the consideration of the things more immediately pertaining to the earth and to the hard crustaceous matter with which our globe is surrounded, we will briefly refer to the laws according to which it pursues its course fom the sun to its ultimate orbit, or the one which it describes at the present day and which it renews every year. From what we have already stated, it is evident that the earth has already travelled a considerable distance from the sun; that as soon as it commenced its course freely through the vortical region, it began to rotate on its axis and revolve round the sun; that at first it described only small circles, then gradually larger according as it reached a greater distance from the sun. At first the times it measured were only years of short duration, nay, it could comprise a whole age within the limits of our present year; in the course of time the duration of its years was gradually extended until they finally reached their present limit, beyond which they are unable farther to proceed so long as the state of the solar vortex and axillary gyration of the earth continue as they are. Now since the earth, in its exit from the centre or sun, described spiral orbits, it may be well to know the laws of its progression and momenta, or the rate of velocity with which it pursued so lengthened a course. That our argument may observe a regular order, we shall first premise a few remarks on the vortex of the sun and of our earth.

1. *That in the solar vortex formed by the spiral motion of the*

elements from the centre to the circumferences, the elementary particles are not only reduced to a regular situation and motion, but are perennially kept in this situation and motion by the constant action of the sun in the middle of the vortex. That consequently there is in this vortex a force or tendency from the centre and to the centre, according as the bodies are lighter or heavier than the volume of the element. In our First and Second Parts we have abundantly shewn that the first and second elementaries can move only in a spiral and vortical direction; that they cannot, for instance, be put into any other motion than such as accords with their mechanism and figure; that they are then in their veriest and most natural situation when they assume a vortical arrangement; that they spontaneously and unanimously conspire to this motion; that they so dispose themselves as to adapt even their very figure to their distance and motion, or that when compressed they tend to a more rapid gyration than when dilated, more rapid at a smaller distance from the sun than at a larger; that they cannot be quiescent unless there be no centre around which they can gyrate; that the perpetual active vivifies, renews, and as it were preserves the perennial action of the particles of the element; not to mention other particulars of which we have above spoken. If such then be the natural situation of the parts, and if their motion be spiral, it follows that bodies forming a volume of this kind tend either to or from a centre; for the current of motion itself forms continuous spires from a centre to given circumferences; the geometry of the parts is similar, but adapted from the centre to the circumferences by compression and dilatation; a very heavy or light body in a stream of this kind is carried in the direction of the current parts; for while it is among the parts which are in motion it cannot be quiescent but must follow in the current. If the body be too heavy to follow in the exact spiral course of the current, it notwithstanding continues to be driven by a certain force from a centre or to a centre; for all spiral motion tends to some further limits and to circumferences of some kind; if the body does not travel along all the innumerable spires described by the parts, still it travels some fewer; or if not a fewer, still at least one; or if not one, still it pursues the course of the diameter; for a spiral motion is in the direction both of circles and diameters. If a hard body cannot follow in the course of the circle, it follows in that of the diameter; the various spires are acting continuously one after another, each adding its own momentum, thus urging the body by a force most highly mechanical in an altitudinar direction or directly along the diameter, and forcing it on by its convolutions in a manner not unlike that in which the helix raises weights; so that by adding step to step and one force to another, the body is driven progressively onward. Thus it is that in the solar vortex there is a centripetal and centrifugal force.

2. *That the earth perpetually revolves round its axis like a large finite, and spontaneously; that is to say, by reason of the nitency of its individual parts constituting its central globe; and thus that it begins to measure the intervals of day and night the moment of its making its exit from the sun; from which moment also it seems to perform its axillary revolutions more rapidly than it does at a farther distance from the sun, when a considerable portion of it is consumed in the formation of ether, air, water, and terrestrial matter, and the parts of the earth become more closely bound and connected with each other by means of an incrustation consisting of different entities.* Since, according to our theory, the earth consisted at its commencement only of finites of the fourth genus, and these finites are of such a character as always to tend to become actives; since according to the principles in Part I. and III., these finites put their compound finite not only into a progressive but also into an axillary motion; and since in her motory relations nature is similar to herself both in her largest and least operations, the axillary motion of this large finite arises from that of her smaller finites, and has its origin at the same moment in which it issues from its parent. At first its motion is more rapid when it consists of a larger combination of individuals, and before any portion has been consumed in the formation of ether, air, water, hard and earthy crust; at which period its individual parts are not held so fast and coerced within their limits, but that, in accordance with the force they exercise, the earth can freely perform its natural motions.

3. *That the earth, like a large active, has a tendency to a second motion, or to circles round the sun, by means of which it*

forms a surface not unlike the forementioned actives; that still however it is carried round the sun principally by the stream of the solar vortex. Hence that from the beginning of its excursion it is perpetually meting out, by its circular and periodical revolutions, winters and summers, springs and autumns, or, in fine, years, but such as are more shortly and rapidly performed than at the present day. This large finite, or the earth, when in a free state could not but actuate itself, according to the theory of actives in Part I., and the theory of fire in our present Part. On the commencement of its diurnal revolution, therefore, it immediately began to distinguish its times into summer, autumn, and the other seasons, but since it then possessed a more rapid velocity, since there was then nothing to impede or coerce the free motion of its individual parts; since also its periodical revolutions were then more confined and more rapidly described round the sun, it follows that together with the years all the seasons likewise were shorter in proportion to its greater proximity to the sun.

4. *That the earth, moving among the elementary particles of the solar vortex according to its magnitude and the velocity of its motion, formed around itself a vortex, just like the small magnetic corpuscle treated of in the Second Part; consequently that at the commencement of its excursion it described first a larger, then afterwards a smaller vortex.* See Part II., Chap. I. It is a law of mechanics, that a body moved rapidly describes a larger vortex than a body moved slowly; it is also a law of mechanics, that a larger body describes a larger vortex than a smaller; the greater the mass and velocity the greater the impetus or weight; for the impetus and weight are compounded of the mass multiplied into the velocity. Hence a larger and heavier body in motion possesses a greater impetus and weight than a lighter body, or a body in less motion. If a similar or greater degree of velocity be communicated to a body of larger mass, it can exercise a greater impetus in circulating the elementaries, which on their part also spontaneously follow in its course, having the greatest possible tendency to motion. Hence we see formed a greater and smaller vortex of the particles of the first and second element, in proportion as the mass in motion is greater, and in proportion as there is a greater motion in the mass. Hence it

follows, *that the earth, when thus in the centre of its vortex, is in its natural situation. That it cannot travel out of its vortex, nor move unaccompanied by the vortex; but that so long as its axillary motion remains, so long remains also the vortical motion of its parts, always determined and proportioned to the size and velocity of its body.*

5. *That the vortex formed round the earth aims at an equilibrium in the solar vortex, that is to say, occupies the place where it can be in a state of equilibrium. That were the vortical motion greater or swifter, it would seek a different locality from what it would were the motion less or slower.* A smaller vortex formed in a larger separates itself as it were from the larger by reason of its motion; for the elementary particles which are at a distance from the centre of the larger vortex cannot thus dispose themselves into the motion and position of the particles in this vortex, because they now revolve around another centre; consequently within the smaller vortex they are in a different state of expansion and compression; hence those which flow without the vortex are either more expanded or more compressed, consequently the volume which is in vortical motion and rendered lighter or heavier, can subsist only at that distance from the centre where it finds an equilibrium of weight; just as we perceive lighter volumes rising in the atmosphere ascend to some higher and given region, and take their place at that given altitude in which an atmospheric volume of equal bulk is of the same weight; that is to say, in which the two equilibrate each other. The smaller vortex therefore seeks a state of equilibrium at a greater or less distance from the centre of the larger vortex, or among its elementary particles more or less compressed. *This however does not prevent the elements of the solar vortex from exercising a pressure within the minor vortex also, in proportion to their altitude, and similarly in every direction. Nor does it prevent them from exercising this pressure, if smaller vortices be formed within the larger; whence from the general pressure of the solar vortex there arises a tendency to the centre of the earth.* This might be proved by a variety of facts, as well as from known geometrical principles. Smaller gyres described in water, the ether, and the air do not prevent a large one from operating in any direction conformably

to its own mechanism. A volume in the highest degree of motion, whether it be one of water or air, does not prevent the existence of a pressure according to its altitude or column, and this even in the most rapid torrent. The expansion of the air produced by the most intense fire does not prevent the air from being superincumbent and pressing upon the volume beneath it; nor does it prevent the mercury in the barometer from attaining to its exact height, although the air within the expanded volume be rarefied to such a degree as to form an equilibrium of expansion. Not to mention other particulars, which we shall reserve for our observations especially devoted to this subject.

6. *That the greatest motion of the solar vortex is at the centre, and becomes gradually less as it approaches the circumferences, so as to be least or none in the ultimate circumference, and this too in the plane of its zodiac.* For if the sun be the fountain of motion, and if this motion spread from the sun spirally toward the circumferences, so that one particle moves onward another, it follows that where the first motion is, there also is the greatest; that the acting cause is stronger than the effect, and is gradually weakened by a certain renitency of the distant parts; and hence we see that in the solar vortex the planets which are nearer to the sun revolve with a greater velocity than those which are more remote. That the motion takes place in the plane of the zodiac, may be seen in Part I., Chap. VI., and various other places.

7. *That the earth, which is compelled to form innumerable spiral circles in its passage round the sun, travels with a velocity gradually diminishing in proportion to its distance from the sun; that its motion also is diminished according to the circles it describes, or its annual gyrations in a simple ratio; but in relation to the diameter or right line drawn perpendicularly to the sun, in a duplicate ratio.* In the spiral orbit described by the earth, the diminution of its motion can be no other than in a simple ratio, because it arises only from the resistance of the fluent particles; and since of these particles there is a successive series extending spirally from the centre to the circumferences, the motion is every moment retarded by this series at every successive step; and inasmuch as the cause of retardation

and resistance is simple, the ratio of velocity is consequently simple. So that in a simple ratio, according to the spiral circles, the greatest velocity is in the centre, a less degree in the circumferences, and the least in the ultimate circumference. Hence at every step of the progression in the circumferences the velocity becomes less; less for instance in *b* than in *h* (Fig. 1, Vol. I., p. 106), less in *h* than in *i*, less in *i* than in *k*, least in *d*, and none in *e* or *g*, which is the simple ratio of the lengths from one point in the arc to another. Since all resistance arises from the series of particles flowing into the same figure; and since this resistance can be considered only according to the figure into which the series of particles flow, it follows according to the figure that the ratio of the velocity is simple, but not so according to the diameter from *a* through *bc* to *d*. Now inasmuch as the fluxion is spiral, and every moment is directly receding from its centre more and more through the radius or diameter, there arises hence another ratio which we have to consider both in the spiral series and at every distance from the centre; consequently now that we have the accession of another ratio, we have, according to the general rule, a duplicate ratio from the centre to the circumference, or a ratio according to the diameter from *a*, *b*, *c* to *d*. Thus when a body falls through any medium, if there be added every moment to the natural simple arithmetical ratio of its motion a constantly similar degree of velocity, there hence arises a duplicate velocity, or the ratio which simple ratios have to their squares. The earth therefore, as regards its recession in a diametrical line, seems to diminish its velocity in a duplicate ratio.

8. *That with regard to the velocities in the solar vortex at the several distances from the centre, they are in the diameter in the subduplicate ratio of the distances from the ultimate periphery, or that in which all the motion ceases.* In order therefore to obtain the velocity of the vortex moving in any circle, and consequently the velocity of a planet or earth moving in this circle and round its own centre, it is to be remembered that this velocity is in the subduplicate ratio of the distances from their ultimate periphery. Let the distance from the ultimate periphery $bc = d$, the velocity $= v$; then, according to the common rule, $d : D :: v^2 : V^2$; that is to say, the velocities are in the sub-

duplicate ratio of the distances from the ultimate periphery. Or if the whole distance or radius extending to the centre $=x$, and the radius of the given distance be $x-d=r$, there will arise this proportion; $x-r : x-R :: v^2 : V^2$, or the velocities are in the subduplicate ratio of the differences of the radii. In like manner in the solar vortex, the times are in the subduplicate ratio of the distances from the ultimate periphery to the centre; for, according to the common rule, the times are as the velocities. If however the vortex be such that the least motion is in the centre, and the greater in the direction of the circumferences, then the velocities and times will be in the duplicate ratio of the radii from the centre.

9. *That if two planetary bodies be in motion in the solar vortex, each at a different distance from the centre, but moving in a circle or ellipsis round the sun, the squares of the periodical times of each body will be as the squares of the radii divided by the distances or complements of the radii extending to the ultimate periphery.* In Fig. 1 (Vol. I., p. 106), let $dc=d$, or the distance from the ultimate periphery. Let $ac=r$, or the radius of the same circle. Let $db=D$, or the distance of either planetary body from the ultimate periphery. Let $ba=R$, or the radius proceeding from the centre. Let $da=x$, or the whole radius from the centre to the ultimate circumference. Then the squares of the periodical times of the circle c are to the squares of the periodical times of the circle b, as $\frac{r^2}{d}$ to $\frac{R^2}{D}$; or what is the same, $t^2 : T^2 :: Dr^2 : dR^2$. The reason is, that the velocities at c and b in the figure are according to the general rule thus obtained, $d : D :: v^2 : V^2$, or $Dv^2 = dV^2$. Therefore $v = \frac{d\frac{1}{2}V}{D\frac{1}{2}}$, or the velocity in the circle c; and again, $V = \frac{V\frac{1}{2}c}{d\frac{1}{2}}$, or the velocity in the circle b. If this velocity be divided by the periphery of the other circle, we then have the periodical times. Instead of the peripheries or circles let us take the radii, because these are similar to, or are in the same ratio with, their circles. In this case $ac=r$; and r divided by $\frac{d\frac{1}{2}V}{D\frac{1}{2}}=\frac{D\frac{1}{2}r}{d\frac{1}{2}V}$; which

is the periodical time of the circle c. The periodical time of the circle $b = \frac{d\frac{1}{2}\text{R}}{\text{D}\frac{1}{2}\text{V}}$. Now instead of v, or the velocity of one circle, let us take its representative $d\frac{1}{2}$, and instead of V let us take its representative $\text{D}\frac{1}{2}$; we have then the periodical times thus, $\frac{r}{d\frac{1}{2}}$ and $\frac{\text{R}}{\text{D}\frac{1}{2}}$; and squaring these we have $\frac{r^2}{d}$ and $\frac{\text{R}^2}{\text{D}}$; therefore $t^2 : \text{T}^2 :: \frac{r^2}{d} : \frac{\text{R}^2}{\text{D}}$, according to our proposition.

If however the vortex be so formed that its least motion is in the centre, and its greatest at the peripheries, then the squares of the periodical times will be as the cubes of the distances from the centre; or $t^2 : \text{T}^2 :: r^3 : \text{R}^3$.

On a further consideration of the subject, however, we shall find there will be a considerable difference, if the two planetary bodies vary respectively their distance from the middle, or in the middle of the vortex. If each body be not far distant from the middle of the vortex, or if in the two circles they are almost equally distant from the middle, then there is not much difference between them; D will be almost the same with r, or $\text{D} = r$ nearly. In like manner $d = \text{R}$ nearly; and in this case, or in the middle of the vortex, or else on each side equally from the middle, if instead of D we put r, and instead of d we put R, we shall have the forementioned ratio of $t^2 : \text{T}^2 :: r^3 : \text{R}^3$, or the squares of the periodical times are as the cubes of the distances from the centre.

10. *That two planetary bodies moving at unequal distances from the sun or centre, differ in their velocities; that these velocities are as the rectangles of the radii and times reciprocally.* For if $t^2 : \text{T}^2 :: \frac{r^2}{d} : \frac{\text{R}^2}{\text{D}}$, and if instead of d we substitute v^2, or the velocity which is its representative, it follows that $t^2 : \text{T}^2 :: \frac{r^2}{v^2} : \frac{\text{R}^2}{\text{V}^2}$, or what is the same, $v : \text{V} :: \text{T}r : t\text{R}$, according to our rule.

If however the motion increases from the centre to the circumference, then the velocities will be in the subduplicate ratio of the radii, or $r : \text{R} :: \text{V}^2 : v^2$.

In this case, however, if the two planetary bodies are not far distant from the middle of the vortex, or if they are almost equally distant from the middle of the vortex, namely, one on one side of the middle and another on the other side, then the calculation for each almost coincides, so that d is almost equal to R, and D to r; hence whether we make use of the former or latter in our proportion, the result will be almost the same. In case however the distances from the middle differ much from each other, the result will be proportionally different.

11. *That if two planetary bodies gyrate at unequal distances from the solar centre, the centripetal forces are as the distances from the ultimate periphery divided by the radii.* If c be the centripetal force, then according to our rule $c : C :: \frac{d}{r} : \frac{D}{R}$ or, $c : C :: dR : Dr$. The reason is, that the velocity at the first distance from the ultimate periphery d (viz. in the circle c,) is thus obtained; $d : D :: v^2 : V^2$; or $Dv^2 = dV^2$, and $v^2 = \frac{dV^2}{D}$ and $v = \frac{\sqrt{dV^2}}{D\frac{1}{2}}$. The intermediate velocity is a proportional between the radius and centripetal force: let this radius $= r$; then $r : \frac{\sqrt{dV^2}}{D\frac{1}{2}} :: \frac{\sqrt{dV^2}}{D\frac{1}{2}} : c$, or $\frac{dV^2}{D} = c, r$. Since V^2 is similar to D, and may be substituted for it, we have $\frac{D}{R} = C$, &c.; whence $c : C :: \frac{d}{r} : \frac{D}{R}$, according to our proposition.

In the vortex, however, whose motion is less at the centre and greatest at the circumferences, the centripetal forces are reciprocally as the squares of the radii, that is to say, $c : C :: R^2 : r^2$.

In the middle of the vortex, or at equal distances from the middle, there cannot be much difference between d and R, and between D and r, hence the proportion into which each enters agrees with the other.

Inasmuch as it may be shewn not only *à priori* or from principles, but also *à posteriori* and from experimental fact, that bodies moving in the solar vortex perform more rapid revolutions in the peripheries nearer to the centre than in those which are more remote from it, I may venture with some degree of confidence to apply the foregoing analogies to the earth and the planets.

CHAPTER XII.

ON THE PARADISE FORMED UPON OUR EARTH, AND ON THE FIRST MAN.

We have thus briefly recited the manner in which our earth surrounded itself with ether, then with air, and lastly with water; we have stated that as soon as it began its journey, it revolved round its axis, and immediately also round the sun; and that from its infancy therefore it began to measure out the lengths of years and days. We have explained how its gyrations were at the commencement more rapid, then in process of time slower, till, in arriving at the orbit it now annually describes, it reached its utmost limit of slowness. Here we left it, surrounded with water without a shore. Not, however, to leave it to the lawless fury of a flood, we here resume the subject, and explain in a few words in what manner shores were now added; that is to say, how it was that dry land was acquired; how the waters superinduced upon themselves a crust, which not only coerced them within given limits and kept them within an enclosure, but also how all that we now find in the vegetable and mineral worlds was enabled to enter into the crust; how heaven also not only deposited its seeds in this crust, but also gave them germination and expansion. This however we shall explain but briefly, inasmuch as the subject is one which strictly belongs to a treatise on the mineral and vegetable kingdoms. Not to forsake the earth then in its state of inundation, we shall next in order briefly enquire into the origin of the mineral kingdom. With respect therefore to the incrustation we have mentioned, it is to be observed;

AA 2

1. *That this crust formed itself upon the water by the dissolution of the parts in the water, and the interjection of finites which emerged to the surface, and formed upon the water a crust which continually increased by an addition of parts one under another.* It would be a tedious task to explain everything relating to the origin of hard bodies composing the terrestrial crust from its bottom to its surface; we may however observe thus much in general, before treating of the mineral kingdom,—that from operations of most diversified causes, as also at various distances from the sun; from the immense variety of changes which the earth underwent in its course from the sun, first at a more rapid, then at a slower rate, first in the immediate presence of the sun and under its rays, then at a remoter distance; that portion of water which was of looser texture, and the parts of which had from various causes been set free, occupied the interstices of the other portions of water, and so together with these emerged to the surface, accompanied by fourth and fifth finites which mixed themselves up with them. From these arose compound entities of different forms, which produced a crust, as also other entities flowing freely, because adapted to the interstices of the water, and giving rise to a variety of phenomena. On this subject however we have here said enough.

2. *That the earth underwent innumerable changes before arriving at its present circle or orbit, that is to say, changes as numerous as the circles it completed, or the different distances of these circles from the sun; as numerous also as were the degrees of velocity in the course of its annual and diurnal revolution; in fine, that every day and hour it underwent some new change, during its journey from the sun to its present orbit.* The number of changes therefore it experienced may be concluded from this, that when issuing from its chaotic state it was at first naked, and was so near the sun as to appear comparatively diminutive, yet able to look closely into the vast solar ocean; that afterwards every hour, day, and year it receded to a farther distance, and in relation to the immense solar disk became smaller and smaller, because subtending a continually less angle; that it thus became in a less degree surrounded with the solar rays; the farther it receded the less became its relative size, and the greater was the difference of manner in which the solar beam

was received on its surface. Every moment was it changing its locality and distance from the sun; so that the sun could operate upon it when it was near in a different manner than when it was farther off, and with a variety every successive moment. Thus every instant it was experiencing some change in its relation to the sun, which was as it were ever changing, producing, and vivifying everything in its vortex. In like manner it was ever undergoing some change as to its circumfluent elementaries, which near the solar centre are in a greater degree of compression and a more rapid motion, and farther from it are in a less; so that what in the first instance these elementaries united, they at other distances either dissolved or united in a different manner, and *vice versâ.* The changes the earth experienced are evident also from these further considerations; that it was at first entirely uncovered, then after this enveloped with ether, and in this state received the solar heat in a different manner from what it did before, and in a manner again continually differing in proportion as the ethereal sphere became larger and larger; that it afterwards became enveloped with air, the column of which grew continually higher, and thus was capable of being set in motion in a different manner when it was low from what it could when it was high, and in ways differing from each other at different distances from the sun. When finally it became surrounded with water, it then assumed a still different state, and in this state also received the rays of the sun in various ways, differing according to its distance from the sun. Its states were also varied by first its more rapid, and afterwards its slower gyrations round its own axis; by its completions of longer and shorter years, which varied according to the variation of its motion, and consequently according to the temperature of the newly-formed ether, air, and water, or to the seasons, so that the earth must necessarily have undergone a variety of new vicissitudes. To this we may add, that at every different distance its ecliptic was different, its equator being exposed to the sun in one place more directly, in another more obliquely, just as we see in planets nearer to the sun and farther from it; in which cases different zodiacs are traced, according as the different solar or proximate vortices more or less alter the direction of the axis; in this case therefore the seasons of the year must have been constantly dissimilar, such as the winters, summers, springs, and autumns: the frigid zones also could not always have been frigid. In fine, it is impossible to enumerate the various changes which the earth must have necessarily experienced before it had reached its final destination. From all these considerations however we are at liberty to infer, that the system of our earth must have undergone innumerable changes before it could have been fully completed, and have consisted of so many series of things simultaneously and successively arising; or before it could have been enriched with so many entities as would suffice to supply the mineral, vegetable, and animal kingdoms; before also it could have received its seeds, unfolded and expanded them, and so delightfully and variously adorned its own surface.

3. *During that state of the earth in which its revolutions round the sun and its rotations upon its own axis were more rapidly performed, or when the earth measured out shorter days and years, the whole surface of the earth was surrounded with one perpetual spring; a season the most highly adapted to the purposes of generation and procreation. Without this perpetual spring no seeds would have germinated, nor could the various subjects of the animal and vegetable kingdoms been produced.* That our earth formerly measured out days and years of shorter duration than the present seems to be confirmed by the age of our first ancestors; for we learn from Scripture that the lives of some extended to eight or nine ages, or that they lived to see ten and even thirteen generations of their own families, and that it was but of slight account for them to live from one to three ages. If, however, the earth at that time performed its annual revolutions more rapidly, and if it measured out a year to its inhabitants within the space of a few of our present months, they might in this case have lived through several ages, when yet the duration of these ages, or the greater number of birthdays occurring in one life, might not much have exceeded as to duration a single age in the present day; whence they could not be said so properly to have lived to a great age as rather to have lived a great number of years; for if they could have reckoned as many summers as the inhabitants of Mercury or Venus, the number of their years would be greater than ours, but the duration itself equal. Could the antediluvians therefore

now make their appearance amongst us, their surprize would be awakened by the shortness of our spring and the length of our autumns and winters; they might perhaps chide the length of our annual revolutions and complain of growing old before they had fulfilled their wonted number of years. But this by the way. It is evident from what we have stated, that there once was a time when the earth in completing its year occupied only a few of our present days; on arriving at a greater distance from the sun, in completing its year it occupied the space of our present month; afterwards two months, then three, and so on successively till as the years lengthened they reached their present duration. Thus the planets which are nearer the sun reckon their years by our months; while those which are farther off extend the duration of their year so as to make it comprise several of ours. If Saturn divided its year into twelve months, a year of our earth would not equal two weeks of Saturn; the nearer therefore planets are to the sun the shorter are their years, the shorter therefore are the seasons of the year, and in this case a summer would scarcely last the length of our month, neither would an autumn or winter; as soon as the summer had commenced, autumn would supervene, which would be as rapidly followed by winter; thus after a brief interval summer would return with all its vegetable produce, and the operations of nature would observe the briefest cycles. The summer therefore could not infuse any warmth into the earth which was not soon dissipated by the supervening autumn and winter; neither could the winter, (so rapidly succeeding the summer and hence tempered by its lingering warmth,) occupy the zones with its cold, without the rapid return of spring and summer dissipating these chills. The duration of the seasons thus being shortened, they would become as it were confounded, and collectively would form only one perpetual spring. Moreover if the lengths of the days and nights were extremely short, the heat of a summer's day infused into the earth would become dissipated by the cold of the night and the cold of the night by the heat of the day. In this case the vernal temperature would be the same as if a thermometer were appended to a cylinder and the cylinder rapidly rotated before a fire; in which case the spirits of wine in the thermometer would rise to no higher degree than temperate, unless the motion were too rapid. In this manner then did once a perpetual spring surround the earth, as indeed was maintained by the ancient philosophers, who were guided only by the light of reason, although the cause of the vernal duration was a subject of which they were ignorant. Ovid therefore makes the following beautiful allusion :—

The golden age was first ; when man yet knew
No rule but uncorrupted reason knew,
And with a native bent did good pursue.

* * * * * *

The teeming earth yet guiltless of the plough,
And unprovoked, did fruitful stores allow :
Content with food, which nature freely bred,
On wildings and on strawberries they fed ;
Cornels and bramble-berries gave the rest,
And falling acorns furnished out a feast.
The flowers unsown in fields and meadows reigned,
And western winds *immortal spring* maintained.
In following years, the bearded corn ensued
From earth unasked, nor was that earth renewed.
From veins of vallies, milk and nectar broke,
And honey sweating through the pores of oak.

Translated by Dryden. *Garth's Edition.*

Again the poet, when signifying that the seasons were shorter than the present, observes :—

But when good Saturn, banished from above,
Was driven to hell, the world was under Love,
Succeeding times a silver age behold,
Excelling brass, but more excelled by gold.
Then summer, autumn, winter did appear,
And spring was but a season of the year.
The sun his annual course obliquely made,
Good days contracted, and enlarged the bad.

Ibid.

Virgil :—

In this soft season, let me dare to sing,
The world was hatched by heaven's imperial king,
In prime of all the year and holidays of spring ;
Nor other was the tenor of the year,
When laughing heaven did the great birth attend,
And eastern winds their wintry breath suspend.

Georgics, Book ii., p. 337. *John Dryden.*

Alcimus Avitus :—

Nor winter here held his alternate reign ;
Nor after winter chills shone burning suns ;

> . . . . But here soft *spring* her constant reign maintained ;
> Unknown as yet the ruthless southern blast.
> And ever underneath the dewy heavens
> Into clear air the gathering mist dissolved.
> Book i., p. 11.

The ancient philosophers, in their allusions to this period, supposed that paradise was situated in some higher region than the one occupied by the surface of the earth in the present day, so that it would seem as if they thought the earth was nearer to the sun; and hence Plato in his *Phædo* makes mention of a certain ethereal country. Hesiod mentions the garden of the Hesperides beyond the ocean; Moses also speaks of a fiery flaming sword separating the first man from paradise. Thus by one perpetual spring the whole terraqueous globe was rendered one universal paradise; all nature was in her infancy, sportive and smiling. Then was the reign of the golden ages, in which according to the philosophy of the ancients the deities were born. Then were seen Flora and Ceres perpetually reclining on the earth upon their gay and grassy couches. Diana with her nymphs traversed the woods. Jupiter, Phœbus, and the other gods, lived in daily intercourse with men, and celebrated their loves in every grove. Pluto emerged from his Tartarean shadows into the beams of day, and ran off with Proserpine; and Venus with her son Mars were engaged respectively in love and battle.

Had not a perpetual spring surrounded the earth, the earth could never in its various vicissitudes have received such a variety of seeds, nor for so long a time beyond the age of infancy have prolonged its existence, after having received life as it were in the womb of its mother; hence a perpetual spring was the most efficacious and almost the only means by which the generation of things could have been promoted. It was commanded at the creation of the world that the soil should bring forth its seeds; the seed its germs and tender shoots; the sea its fishes: and the earth its animals; not to mention other things which indicate that the Omnipotent produced and perfected the world by the use of media, which we may from reason presume to have been those innumerable vicissitudes and that perpetual spring by which alone the various objects of the world could have been brought into being. And how wonderful are those operations of nature by which the earth brings forth her seeds; and which not only expand into shrubs, and flowers, and herbs, but also continually renovate themselves! How wonderful is nature also in the animal kingdom! so that although perpetual spring began gradually to leave the earth and to recede to a considerable distance, although winters and unequal autumns succeeded, yet all things continued their life the same as when under a constant vernal temperature! Here let us pause with astonishment, let us admire and adore that Infinite Providence who has set before us such wonderful manifestations of his wisdom, and to whose unceasing care everything bears such palpable testimony.

When therefore this globe had luxuriated in its various vegetable productions, and animals of all kinds had come into being, then was the first man introduced into paradise, having been created into all the harmony of the visible world; being made partaker of a more subtile or of a rational aura, in order that he might know how to render the various parts of creation around him still more perfect, by doing what could not be effected except through the medium of a living and rational agent endowed with a material body: a being who should enjoy the charms and varieties of nature; who should learn wisdom in order that he might know to reverence, love, and worship that infinitely wise God who is the Author and Builder of the universe; and whose better and more refined nature, though clothed with a material garment, might aspire even to heaven itself. Oh! man, how happy, thrice happy thy destiny; to be born to the joys both of earth and of heaven!

APPENDIX.

Indulgent reader! you have now been presented with a view of the nature of my attempts; namely, a system of philosophical principles extending from the first simple to the ultimate compound, from the smallest invisible to the first visible entity, and hence to the paradise of our earth; a system connected throughout, as I opine, from one end to the other by intermediates. Whoever aims at forming principles, and yet does not commence from the first and simple one, and proceed in regular order to the last, cannot, so far as I am aware, perceive any just connexion between them; for he who stops short in mere intermediates, does not perceive the end of the series either on one side or the other, much less does he see whether these ends have relation to each other, or whether they are connected by intermediates; this was the reason which induced me to undertake the formation of a perfect system. That the principles here propounded are of the most simple nature, any one may see; and that they have hence a perfect similarity to each other, in accordance with what we observe in the phenomena of nature. Every one from the light of reason may perceive that nature acts by the most perfectly simple laws; that all the various things in the world have been produced from one and the same origin and cause; that this cause continues on through every derivative; that it has its first residence in the simple; that it is latent in the first derived ens, or in what I have called the finite; that in this one finite reside the two principles of nature, the active and the passive, from both of which exists the elementary compound; that hence in derivatives resides the like to what is in primitives, in compounds the like to what is in simples, in effects the like to what is in causes; so that nature has her residence in the cause, and reappears in every entity, whence whosoever seeks for her in the effect, will be able to find her in the cause.

Inasmuch then as nature acts by the most simple laws, it may be well to offer a brief summary of the principles of my philosophy. Let us begin from the first simple. 1. In the simple the internal state is a tendency into a spiral motion, and consequently its conatus is of a like kind. 2. In the first finite thence arising there is a spiral motion of the parts, as also in the other finites, so that there is a similarity in all the finites. 3. From this single cause there arises in every finite a progressive motion of the parts, an axillary motion of the whole, and if nothing prevent, a local motion also. 4. If there be a local motion, there hence arises the active, one similar to the other. 5. From finites and actives arises the elementary, one similar to the other, and differing only in degree and dimension. Hence it is evident that I presume the existence of only three kinds of entities, namely, finites, actives, and the compounds of these or elementaries. With regard to finites, I have stated that one is generated from the other; that all the finites thus arising are perfectly similar one to the other, differing only in degree and dimension; that the fifth finite is thus similar to the fourth, the fourth to the third, the third to the second, the second to the first, and the first to its simple; so that he who has learnt the nature of one will have learnt the nature of all. In the same manner the actives are all perfectly similar the one to the other; the fifth, fourth, third, second, and first, being all of the same nature, and like the finites, differing only in dimension and degree. The elementaries moreover are similar one to the other, being compounded of the passive and active, or of the finite and active; finites occupying its surface, and actives its interiors; hence the first, second, third, fourth, and fifth elements are all similar one to the other, and he who has learnt the nature of one will have learnt the nature of all. I have stated also that in every finite there are three distinct motions; a progressive motion of the parts, an axillary motion, and if nothing prevent, a local motion; that so far as I am aware, these are the only motions in nature; or at least, if the motions of entities be granted, it cannot be denied by any rational being, that of all others these are the most highly adapted to the operations of nature. I also observe with regard to these motions, that these likewise proceed from one and the same fountain or cause, namely, the spiral motion of the parts; and that inasmuch as this motion is most highly natural, it is also most highly mechanical, being endowed as we know with every possible mechanical potency and force; and that if it be granted that motion is the cause of things, no other motion can be granted than the one which is highly mechanical. That in the simple, however, inasmuch as there is nothing substantial capable of experiencing motion, we are instead of motion to conceive of state, or of conatus from such a motion to another such motion; a state in which is latent the sole cause and primitive force of all the things which subsequently exist. Of these principles consists the whole of our elementary philosophy, of which we have thus given a summary.

The reader may obtain a fuller view of these principles, by taking a cursory glance of their exposition; beginning from the point where we first enter upon their explanation and tracing them to the end. In writing the present work, I have had no aim at the applause of the learned world, nor at the acquisition of a name or popularity. To me it is a matter of indifference whether I win the favourable opinion of every one or of no one, whether I gain much or no commendation; such things are no objects of regard to any one whose mind is bent only on truth and a true system of philosophy; should it therefore happen that I should gain the assent or approbation of others, I shall receive it no otherwise than as a confirmation of my having pursued the truth. I have no wish to persuade others to lay aside the principles of the various illustrious and talented authors who have adorned the world, and in place of their principles to adopt my own: for this reason it is that I have not made mention so much as of one of them, or even hinted at his name, lest I should injure his feelings, or seem to impugn his sentiments, or derogate from the praise which others bestow upon him. If the principles I have advanced have more of truth in them than those which are advocated by others; if they are truly philosophical and accordant with the phenomena of nature, the assent of the public will follow in due time of its own accord; and in this case, should I not gain the assent of those whose minds, being prepossessed by other principles, can no longer exercise an impartial judgment, still I should gain the assent of such as are able to distinguish what is true from what is untrue, if not in the present, at least in some future age. Truth is but one, and will speak for itself. Should any one undertake to impugn my sentiments, I have no wish to oppose him; but in case he should desire it, I shall be happy to explain my principles and reasons more at large. What need however is there of words? Let the thing speak for itself. If what I have said be true, why should I be eager to defend it?—surely truth can defend itself. If what I have said be false, it would be a degrading and silly task to defend it. Why therefore should I make myself an enemy to any one, or place myself in any opposition to him?

I cannot conclude however without referring to the name of Christian Wolff, who has bestowed so much attention to the cultivation of his intellectual powers, and who has so much contributed to the advance of true philosophy by his various scientific and experimental researches: I refer more particularly to his *Philosophia Prima sive Ontologia,* as also to his *Cosmologia Generalis,* in which he has formed various rules and axioms to guide us in our progress to the attainment of first principles, and a perusal of which has served very considerably to confirm my views; although the principles laid down in the present work had been formed and committed to paper two years before I had an opportunity of consulting his works. In the revision of the present volume I acknowledge myself much indebted to his publications; so much so, that if any one will take the trouble to compare the two, he will find that the principles I have here advanced and applied to the world and its series, almost exactly coincide with the metaphysical and general axioms of this illustrious author. We cannot but acknowledge therefore, in the words of this learned writer, "That in philosophy we must grant a place to philosophical hypotheses, so far as they prepare the way to a clear discovery of the truth."

Again: "Science can make no progress unless we allow of a liberty to philosophize." Again: "Full liberty must be granted to all who philosophize in a philosophical manner, nor have we any reason to apprehend from such a liberty any danger either to religion, to virtue, or to the state."

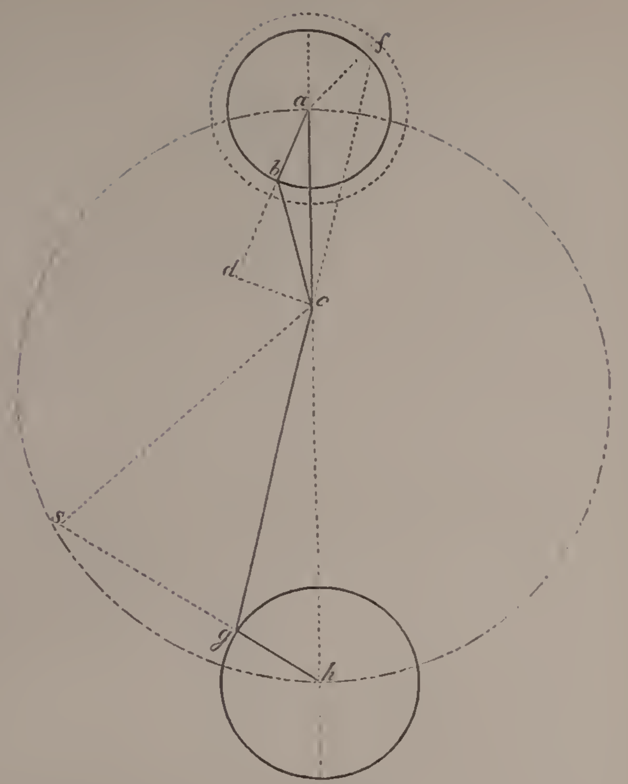
END OF THE FIRST VOLUME OF SWEDENBORG'S
OPERA PHILOSOPHICA.

N.B. These different Figures are designed chiefly to give the different situations of the Poles.

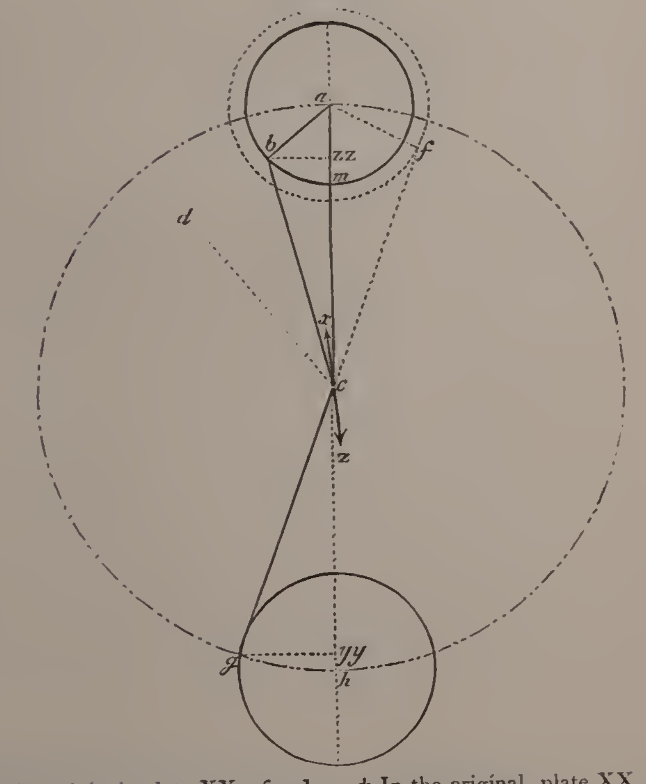
ERRATA IN THE TEXT.

Art. 3, p. 157, for "Fig. 91," *read* Fig. 92. Art. 4, for "Fig. 89," *read* Fig. 90. For "Fig. 91," *read* Fig. 92. Art. 7, p. 158, for "Fig. 91," *read* Fig. 92.

* *Fig.* 89.



† *Fig.* 90.



* In the original, plate XX., fig. 1. † In the original, plate XX., fig. 2.

Fig. 91.

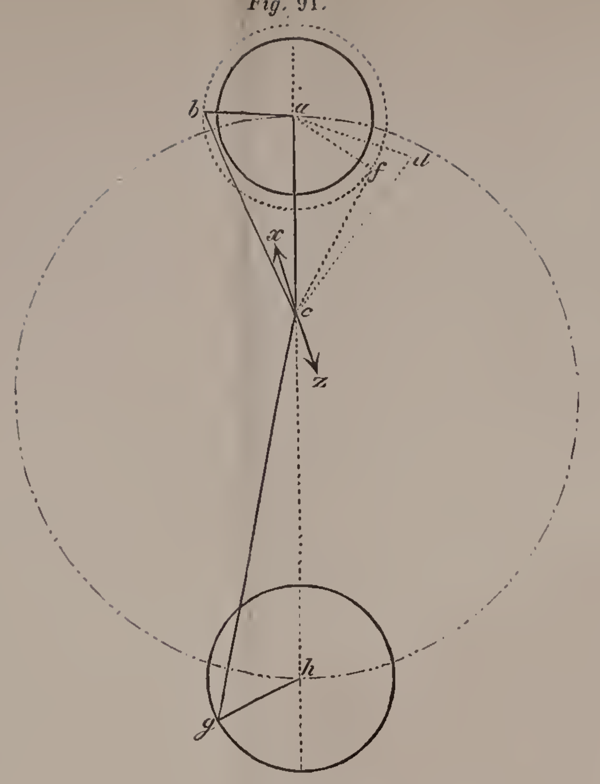
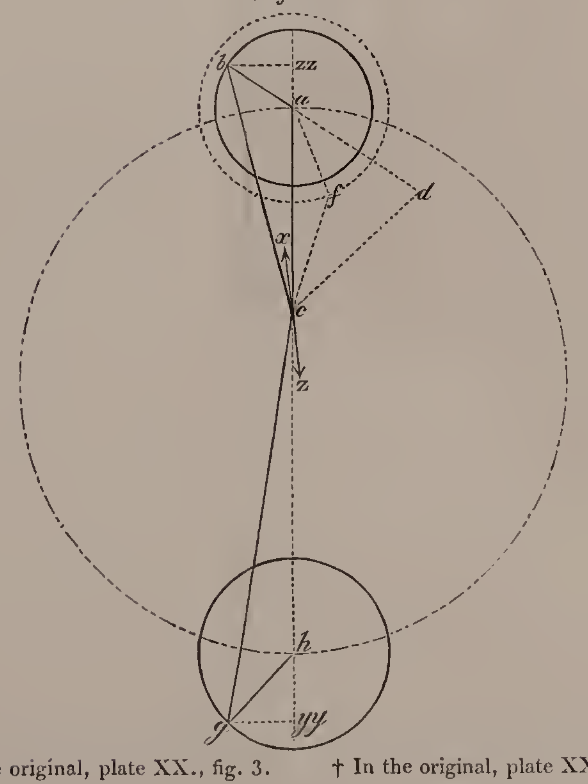
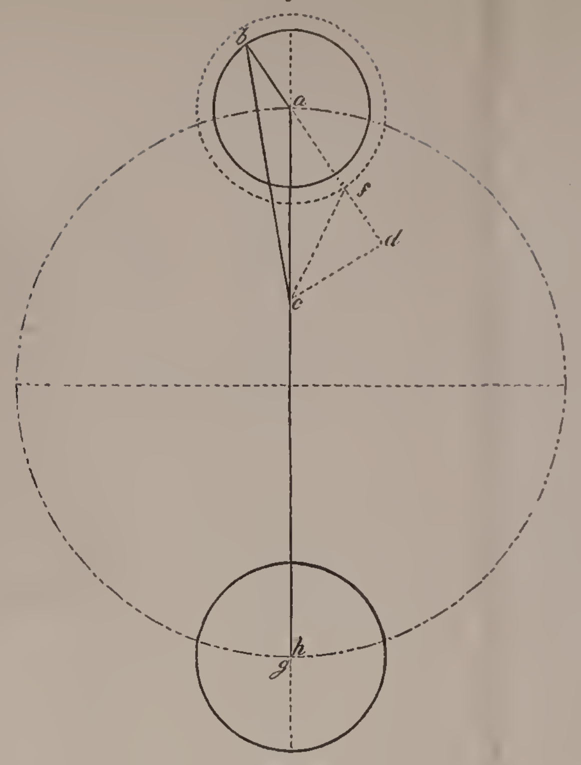


Fig. 92.

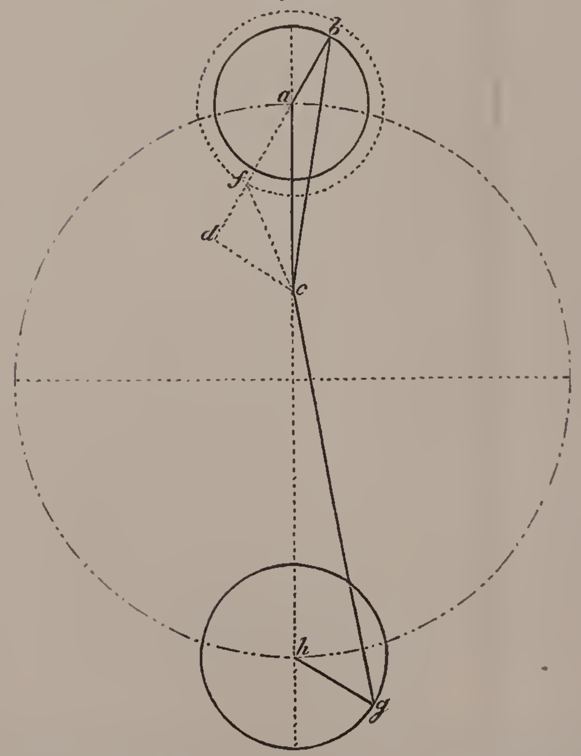


* In the original, plate XX., fig. 3. † In the original, plate XX., fig. 4.

* *Fig.* 93.

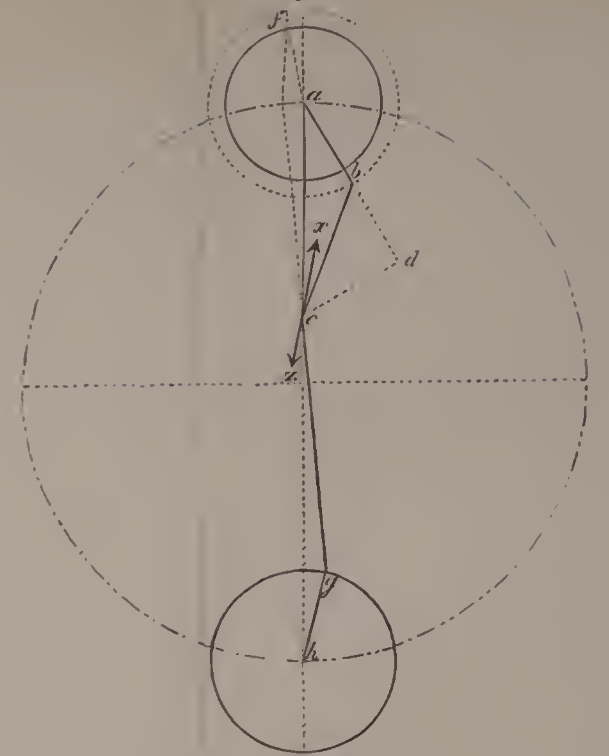


† *Fig.* 94.

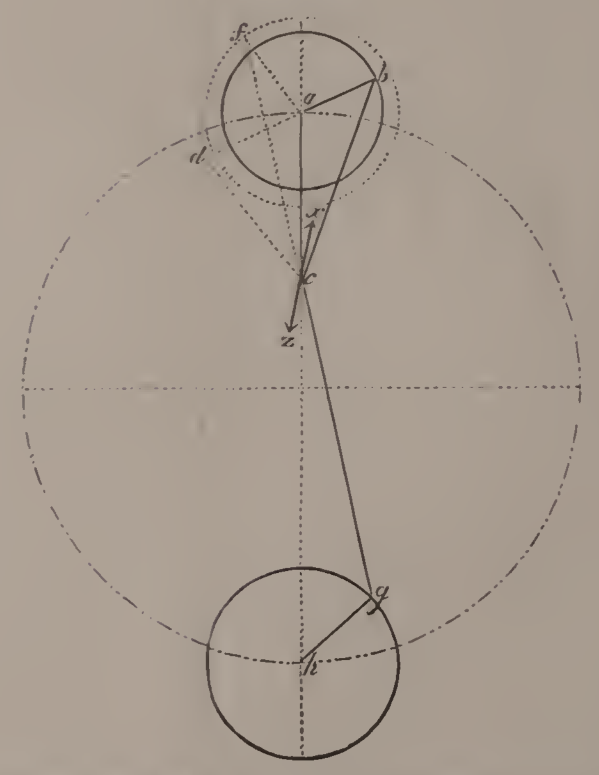


* In the original, plate XXI., fig. 5. † In the original, plate XXI., fig. 6.

* *Fig.* 95.



† *Fig.* 96.



* In the original, plate XXI., fig. 7. † In the original, plate XXI., fig. 8.

PREFACE TO THE TREATISE

ON

IRON,

IN

SWEDENBORG'S MINERAL KINGDOM.

I HERE present the benevolent reader with the first Part of my *Mineral Kingdom,* in which *Iron* is the subject treated of; it being my intention to treat in the same way not only of the other metals, but also of the various salts and stones; and in fact to traverse the whole kingdom to which these belong. I am indeed aware of the magnitude of the undertaking, and that I am attempting to compass and make the chart of a mighty ocean, in a little bark, and with slight and tattered sails; so that I may justly fear lest, as the poet sings,

> "Gemeat sub pondere cymba
> Sutilis, et multam accipiat rimosa paludem."
>
> *Virgil, Æneid.* vi., l. 413.

Notwithstanding which, I had rather brave all dangers, and sail from port, than, poor alike in hope and courage, utterly relinquish the attempt.

I intend to distribute the treatise upon each metal, as here upon iron, into three divisions. The *first division* will comprise the processes and methods of smelting particularly, that are in use in various parts of Europe; and as the methods in vogue in Sweden have come more under my own observation than those employed in other countries, so I dwell upon them longer in proportion. The *second division* will give the various methods of assaying; by which the ore or metal is tried in small fires or assaying furnaces, and its composition examined, in order that it may be the better proceeded with on a great scale. The *third division* will embrace an account of all the different chemical processes that have fallen under my notice, with the characteristics of each; and will deliver numerous experiments and observations which have been made on one and the same metal in the course of solution, crystallization, precipitation, and other chemical changes.

With respect to our first division, in which we give the processes for smelting the different metals or minerals, it is to be observed that it forms a science which is not merely highly conducive to human uses, (as it teaches us not only to examine minerals aright, and with comparative readiness to detect the hidden wealth of particular ores, and to extract and separate the pure metal in greater quantity,) but which also presents us with as rich a store of experimental facts as chemistry itself. For only consider the vast varieties that we obtain in the melting and opening of particular ores, as performed by dry fire; and in the commixtion of ores and metals with fluxes of all sorts; and again in the furnaces and fires that sunder the solid texture and composition of each into its least component parts, and act upon them individually. Furthermore, in this science there are innumerable facts that are mysteries to the learned world, being only known and circulated among the ignoble race of workmen, smelters, and others of the same class, the most obscure of mankind; who go with black faces like Cyclops, and from whom one would think it vain to hope for anything of light, or for anything applicable to the purposes of art. The fact, however, is, that the science which such men possess is purely practical, and founded upon experience and real data; and in this respect is preferable to, or at any rate will bear a comparison with, many of the sciences; for all its details are squared with works. And by consequence, this division of our treatise will afford us clearer and more certain information on some departments of natural knowledge, than the other divisions; which will be particularly the case if metallurgy shall enter into friendly relations with chemistry, and the two join hands, and tend unitedly to one and the same goal. But here I foresee that some will whisper, that the methods of smelting peculiar to different countries, and which have been brought to their present perfection by unremitting labour and experience extended over ages, should not lightly be divulged, or made familiar to the world. For each class of workers in metal has its own secrets, which it deems it a crime to publish. Some, for instance, keep scales and rules with dimensions and proportions exactly cut upon them, and by careful reference to these, or to certain admeasurements of the nail or thumb, they construct their fires, furnaces, receptacles, chambers before furnaces, blast-pipes, bellows-pipes, and the like; and they hide the above rules and instruments in holes or corners, to prevent others from seeing them, and in the meantime they think and even boast that they are better workmen than their fellows. And again there are persons of a like mind, only far higher in rank and condition, who equally are desirous to hold their knowledge for themselves alone, and love to be the reputed possessors and guardians of secrets, that thereby they may pass for learned among the unlearned. People of this kind grudge the public everything; and if any discovery by which art and science will be benefited, comes to light, they regard it askance with scowling visages, and probably denounce the discoverer as a babbler who lets out mysteries. I know it is impossible for me to gain the good-will of this class. The truth is that they think themselves impoverished whenever the knowledge they have becomes the knowledge of the many. But ah! these envious spirits,—how far removed they are from the temple of learning! how abhorred by its patron Muses! How little can they minister at the altars and in the sacristies of Apollo! How low and drooping their aspirations, and how ungenerous their air! For surely no man has a right to hold his knowledge for himself alone, but rather for others, and for the whole learned world. I grant indeed that such characters perhaps possess secrets of some importance which they have got for a small price from those who make all knowledge an article of sale, and whose venal information a few coins will purchase. But why then should such secrets be grudged to the public?

why withheld from this enlightened age? Whatever is worthy to be known, should by all means be brought to the great and general market of the world. The rights of civilized man convince us of this: the natural function of the individual, equally with the laws of the republic of letters, attests and enforces it. In short, unless we all contribute to the best of our power to make the arts and sciences flourish more and more, in order that eventually they may arrive at that goal, which has been the desire of all former ages,—unless we do this, we can neither grow happier nor wiser with time. On these considerations, the first division of our work is constructed, in which the secrets of the art are presented to the public; and we care not if the parties above described burst with spleen, so long as the wise are pleased and satisfied, and the particulars we detail are useful and profitable to them, and prove a gain to science. The longer the earth is inhabited, the more the genius of man is enriched with variety of observations, and the world of letters with distinct qualities of genius, the greater benefit has this our art to hope from ever-new inventions; in earnest of which, in metallurgy alone, an infinity thereof has come to light within this single century.

In the third division of our observations, the reader will find chemical experiments brought together from various authors, yet with an exercise of discrimination and selection; so that none are cited but those that have issued from the best laboratories, and the figments of the alchemists are passed over with little notice, and scarcely furnish us with any data,

> "Officiant lætis ne frugibus herbæ."—*Georgic.* i., l. 69.

For these people cram their books with a farrago of fictions, and as we may say with raw stuff: they put shadows forward, and call them light; and they would have us believe that spectres are real bodies, and that theatrical illusions are facts; and as Virgil says:

> "Fermento atque acidis imitantur vitea sorbis."—*Georgic.* iii., l. 380.

But although I myself have had neither time nor opportunity to submit all their experiments to a fresh examination, I have thought it better to bring forward a few by the more celebrated alchemists. Nevertheless, I warn the reader to believe nothing but palpable experience. Again, as I have not been able to give all the experiments that have been published, and as every year and day is adding to their number, so the reader is at full liberty, and indeed I strongly advise him, to provide himself with an interleaved copy of my work, and to write therein the various desiderata that strike him, and by inserting what I have omitted, to complete the plan here indicated.

It was my wish, besides the foregoing, to give at the end, in a fourth or last division, a theoretical treatise on the several metals, and by principles obtained from experiments, to elicit the use of each. There is, however, so very close a connexion and affinity between all kinds of metals, and likewise between sulphurs, salts and stones, that the quality and texture of the one cannot be discovered or thoroughly seen without a simultaneous view of those of the other also. The mutual embracing of these substances is close indeed. Thus in the bosom of metals there lies a sulphureous, stony, and saline component; besides which, each metal is tethered in close bonds to every other. The consequence is, that experiments instituted upon one kind of metal are nowise sufficient to determine its character, unless we bring to bear also phenomena from the other and kindred metals, and from sulphurs of all kinds, &c., &c. Nor is it possible to gain admission to the knowledge of hard bodies, such as metals, in short, to the subterranean and mineral kingdom, unless the elemental world be known to us on the ground of principles or *a priori,* and unless ether, air, fire, water, and the other elements of the world, be thoroughly investigated. In a word, without a previous explanation of the nature of the elements, it is of no use for the chemist to toil in exploring the character of any of the solids. For this reason, I must waive the theoretical division which I had intended to append to each volume. I think it will be better to collect all such matters into a separate treatise.

The following is a brief Index to the contents of this volume of our subterranean and mineral kingdom, treating of Iron.

DIVISION I. The common mode of smelting iron ore in Sweden. The iron furnaces and foundries of Sweden. Native silver found in an iron mine. The second smelting of iron in the Swedish iron-works. The smelting of the Swedish marsh ore. Also of the lake ore. The

Swedish iron termed Osmund. The mode of smelting at Roslag in Sweden. The second melting in the iron fires at Roslag. The method of smelting the first and second time in France. At Liege. In Italy. At Lesso and Palagio. In England. In Maryland, America. In Russia and Siberia. In Norway, Silesia, Saxony, the Black Forest, Fordenberg, Stiria and Carinthia. The mode once used at Saltzburg. According to Agricola. Attempts at smelting with wood and peat fires. The hardening of iron in Japan, China, &c. The mode used in parts of Sweden for converting crude iron at once into steel. In France. At Saltzburg. In Carinthia, the Tyrol and Stiria. According to Agricola. The art of softening iron according to M. Reaumur. And of casting it into shapes. Experiments for softening iron, made with different substances. Cautions respecting the softening. The ways of extinguishing hot iron. The melting of iron by fluxes. The method of whitening it, or making it like silver. Of welding iron. Of preserving it from rust. The mode of making bar iron in various places.

Division II. The method of assaying iron ore by the magnet. In a crucible. Of assaying it for gold and silver. The methods of ascertaining the quality of crude and malleable iron. The indications derivable from the fracture of iron, according to M. Reaumur. A comparison of iron with steel. Different kinds of iron ore in various places. Iron in earth and mud, vegetables and animals. Hæmatite and schistus.

Division III. Iron filings. Crocus martis aperiens. Ditto astringens. Ditto for making glass. Preparation of red colours in Sweden and elsewhere. Crocus martis antimoniatus. Tinctura martis aperiens and mars diaphoreticus. Tinctura martis. Ditto astringens, Acidulated water. Flowers of iron. Oil of iron. Salt or vitriol of iron. Various products of the hæmatite. The specific gravity of iron. The solution of iron in acids. Effervescence and chemical changes with iron, vitriol of iron, and oil of vitriol. Collected observations on iron. Particles and elements of iron and vitriol of iron in various springs and acidulated waters, with chemical experiments on the waters.

PREFACE TO THE TREATISE

ON

COPPER,

IN

SWEDENBORG'S MINERAL KINGDOM.

The vast abundance and varied store of substances and objects that exist in the bowels of the earth, and which indeed are so numerous that words are hardly plentiful enough to supply names for those already discovered, may well strike us with a feeling of wonder. The subterranean kingdom, from the richness of its treasures, produces not only minerals, metals, stones and earths, but as a general mother yields and renovates the seeds of the vegetable kingdom, and as a nurse supplies all kinds of plants and trees with their peculiar juices; and with the aid of the elemental world, performs the same offices for all the species of living creatures: in short, it labours with abundance, and still may produce an infinite variety of new subjects, provided the elements or the elemental world concur to the effect, and are able to bathe the planet in a new temperature, or to influence it by new conditions. What can be more astonishing than the fact, that in the coldest regions of the frigid zone, in the remote north, almost directly under the stars of the Pole, such rich veins of metal spring and grow, that maturer, nobler, or more luxuriant are not the boast of the torrid climes themselves, with the relatively southern glow of their vertical suns? For only consider the vast issues of copper that the great mine of Fhalun has poured forth during the long period of a thousand years, and that it still pours forth at this very day from its unexhausted womb. In some years, as about 1659, when the grand vein was opened, it yielded no less than 60,000 cwts. In short, the whole floor of the mine, all its doors, caverns, walls, porches, halls and columns, all its open surfaces, shone in every direction with the glittering and golden-coloured rays of this splendid vein: and the visitor might have fancied himself introduced to Venus herself, when the goddess was a bride, in a chamber wrought with choicest decoration, and gladly receiving her guests from Fhalun. Besides all which, multitudes of pieces of native copper were strewed about the mine, both hidden from view, and at the surface. Still further north, as in Lapland, between the 66th and 70th degrees of latitude, where the wintry sun for some length of time neither rises nor sets, where no noon divides the day, because no noon occurs until days and weeks have elapsed,—I mean, under the very Wain and Bear star,—we find veins exceeding rich in both copper and silver, and this, be it observed, under ground covered with everlasting snow, and bound with ice from year to year; and the young and embryonic ore of the former metal is fostered and cherished in the bosom of the gelid soil, although it would seem to love a more genial womb, and to require to be stimulated, encouraged and nourished by the rays of a nearer sun. To say nothing of the mines of Kongsbergen, in Norway, which, for the last century, had often yielded, in liberal plenty, to the cold light of the boreal day, an almost unmixed issue of native silver, and more than once, of native gold, such as we should have looked for alone under happier skies. But I will here give the annual yield from 1711 to 1724, that the reader may the better contemplate what admirable phenomena of nature exist in the mineral kingdom.

In 1711 these mines produced 15,483 lbs., 12 drs. of silver, of which a large part was native, the value of the whole being 172,144 : 56 imperial thalers; the cost of production 107,441 : $67\frac{1}{2}$; the profit 64,702 : $84\frac{4}{5}$ imperial thalers. In 1712 the amount was 15,490 lbs., 10 drs., 3 grs. of silver, chiefly native; the value 174,157 : 18 imperial thalers; the cost 13,265 : $41\frac{1}{5}$; and the profit 60,891 : $72\frac{4}{5}$ imp. thal. In 1713 the produce was 12,630 lbs., 14 drs., 3 grs. of silver; the value 141,246 : 87 imp. thal.; the cost 126,940 : $3\frac{3}{10}$; and the profit 14,306 imp. thal. In 1714, produce 12,689 lbs., 15 drs., 1 gr. of silver; value 148,316 : $45\frac{5}{8}$ imp. thal.; cost 135,057 : $2\frac{3}{5}$; profit 13,259 : $43\frac{1}{4}$ imp. thal. In 1715, produce 9,037 lbs., 10 drs., 2 grs. of silver; value 108,154 : 73 imp. thal.; cost 137,001 : $53\frac{5}{6}$; loss 28,846 : $76\frac{59}{60}$ imp. thal. In 1716, produce 12,744 lbs., 11 drs., 3 grs. of silver; value 159,194 : $69\frac{3}{4}$ imp. thal.; cost 125,417 : $35\frac{1}{5}$; profit 28,777 : $34\frac{11}{20}$ imp. thal. In 1717, produce 21,793 lbs., 2 drs., 3 grs. of silver; value 276,428 : $65\frac{1}{4}$ imp. thal.; cost 138,975 : $7\frac{4}{5}$; profit 13,745 imp. thal. In 1718, produce 19,685 lbs., 6 drs. of silver; value 257,149 : $19\frac{3}{4}$ imp. thal.; cost 157,189 : $74\frac{9}{10}$; profit 99,959; $40\frac{17}{30}$ imp. thal. In 1719, produce 14,824 lbs. of silver; value, 193,948 : $66\frac{1}{4}$ imp. thal.; cost 167,626 : $7\frac{1}{2}$; profit 26,322 : $58\frac{3}{4}$ imp. thal. In 1720, produce 12,760 lbs., 15 drs., 3 grs. of silver; value 168,922 : $42\frac{3}{4}$ imp. thal.; cost 169,362 : $92\frac{1}{2}$; loss 370 : $49\frac{3}{5}$ imp. thal. In 1721, produce 13,671 lbs., 10 drs., 3 grs. of silver; in imp. thal., 178,181 : $3\frac{3}{4}$. In 1722, produce 16,884 lbs., 2 drs. of silver, or 222,285 : $32\frac{1}{4}$ imp. thal. In 1723, produce 16,722 lbs., 8 drs., 3 grs. of silver; or 210,273 : $7\frac{5}{16}$ imp. thal. In 1724, 14,384 lbs., 10 drs., 4 grs. of silver; or 186,796 : $5\frac{1}{4}$ imp. thal.

With respect to native silver we will further add, that a mass of it weighing 279 lbs., and which is now preserved at Copenhagen, was taken in 1719 from the mine of St. Andrew; and in 1727, on the 13th of March, a mass of the like pure silver weighing 245 lbs. was found in the mine of Cron-Printzen. In the Segen-Gottes mine a mass was found weighing 304 lbs., and worth 3,000 imp. thal. In 1726, the Willen-Gottes mine yielded 150 lbs., 7 sem. of pure native silver. During the same year the Gottes Hülff in der Noth Mine, yielded 850 lbs.; and the Sachsen mine, 1,638 lbs. The mine of Segen Gottes, yielded 323 lbs., 2 sem. The mine of Neues Gluch, 1,246 lbs., 6 sem. The mine of Frederick the 4th, 334 lbs., 7 sem. In short, the above mines during that year yielded a grand total of 5068 lbs., 14 drs. of native silver, and of 7,608 lbs. of silver of the richest ores, besides pieces of native silver that were picked out and sold to the weight of 324 lbs. And these results occurred in a region where ice and cold lock the ground, and the chilling northern blast brings with it almost perpetual snows and mists, and even on the surface of the earth fruits can hardly ripen, still less can the elements, seeds and flowers of metals be either deposited, cherished, softened, or warmed by any rays of the sun penetrating the interiors. I have said nothing of the pure silver yielded by the iron mine of Noormark in Wermeland, in lat. 61; but on this subject see the Treatise on Iron, § 1., p. 67.

These circumstances shew that metals may be generated, may grow to perfection and maturity, in cold climates as well as hot, under the Bear star and the Dog star alike, under the northern sky equally with the southern; that metalline veins are not chilled into inactivity although they lie under snow-covered ground, and surrounded by the coldest temperature: and moreover that seeds, veins, matrices and substances, adapted both for generating and receiving metals, are scattered over the whole globe, from pole to pole, and from the rising to the setting sun.

We incline to think, indeed it cannot be questioned, that our planet was perfect in beauty, delicious in variety, and like one vast paradise, before the flood; its surface unbroken and even, with no precipitous mountains or rugged rocks, no deep vallies, no lakes, and no seas: but that after the flood this order was reversed; that it changed its estate, and its surface became broken and uneven, from its outer crust being rent asunder by the waters. Nevertheless it would be wrong to deny that the deluge itself was of use, in opening veins that lay deep in the bosom of the earth, and so providing for the future inhabitants of the planet; and by commingling land and sea, in drawing forth such veins, and lifting them up; (without which they would have lain for ever in Tartarean concealment): and likewise in carrying away from one corner of the world, and thoroughly dispersing, substances and matrices the best adapted both for generating and receiving metals, and strewing them over the earth in different places, equally perhaps in one region, unequally in another. Wherefore to the deluge itself we partly owe the dispersion of metals through all the regions and zones of the terraqueous globe, and partly the opening of the inner bosom of the earth; to say nothing of the real causes and sources of metals, which could have produced no effect, unless substances and parts had been at hand suitable for receiving the veins, and chinks, furrows, or strata for letting them in.

As then the world was brought to perfection by a series of alternations and changes, so it may also be considered, that by the remarkable event, metamorphosis and revolution that the earth was forced to undergo in the deluge, those substances that must otherwise have for ever lain hidden from human eyes in its innermost bosom, were raised up in various places towards the surface, and what was produced in one spot was carried to others also; partly at least by the agency of these mighty waters, weltering and boiling through all their depths. For when so vast an ocean oppressed the planet, when a sea so tumultuous environed the globe, its mighty efforts and whirls could not fail to sweep up and dislodge the sand and sediment at the bottom, and to carry about, and disperse all over, the produce of distant regions,—such as was contained in the cavities or interstices of these materials, whether such productions were heavy or light: by consequence of which, the surface of the planet would become better prepared and adapted for the reception of the nobler substances. But this issue probably would have been beyond hope, had the crust remained entire, and its surface been furnished with only one kind of substances.

But since the crust of earth that lay and pressed upon the subjacent ocean, was probably at least a mile in thickness, it will appear remarkable that such a crust, so densely conglomerated, should have been liable to burst and collapse in places, and in this manner should open such vast gulfs and abysses for receiving the oceans and seas. Nevertheless, as this crust was continually being formed by the aggregation of parts under parts, and therefore grew thicker day by day and year after year; and likewise as the water itself was still undergoing generation, and perpetually coming into existence, and adding to the quantity already produced, it is no wonder if the latter maintained the passages opening through different parts of the crust, (especially since that crust itself would crack and fissure as it dried,) and perpetually mingled the newly-formed waters with those underneath it; which process would go on until at length the subterranean ocean could admit no further streams. The consequence would then be, that the new water would necessarily fill up the fissures and chinks leading down to the subterranean ocean; and then, according to the laws of hydrostatics, that ocean would exert a pressure on its superincumbent and contiguous crust proportioned to the height of the column of water filling the fissures; and if the height was at least a mile, and the area was equal to the surface of the planet, we may easily see what a remarkable and vast superincumbence or pressure the ocean would exert upon the crust; and that, to say the least, it would be powerful enough to raise up parts of it, or to make the already fissured crust take a slanting direction, and cause it to contract still larger cracks, fissures and openings. And as these openings were again and again filled with water, representing conduits standing full, and reaching from the surface to the subterranean ocean, there would be a pressure upon the crust proportioned to the height of such conduits; according to a rule ascertained by experiment; viz., that water presses upon a given area, upwards and downwards alike, according to the altitude and base of its column. The end would be, that the crust, gaping with fissures of vast size, and leaning and slanting in various places, would eventually collapse, and the water rise up in its room, and a deep flood would cover the earth, which would last until it had had time to fill all the abysses, caverns, and openings that the collapsed crust had formed; after which it would seem that the ocean must necessarily return to a level with the surface of the earth. Meanwhile, it is certain, when the ocean was standing at so great a height upon the earth, that it would confound and commingle all things with which it was in contact, and that not only the disrupted earth would give forth its wealth and treasures, (though hidden deep as Tartarus, and though but for these events they would have been hidden for ever,) and roll them down from the toppling mountains, but that the ocean also would scatter these materials, more or less finely subdivided, all over the globe, thus rendering it rich in variety, and open and pervious enough for forming strata, and consequently for receiving metals.

In this way perhaps it may be supposed, partly that matrices and ores were carried to the coldest regions of the earth, and partly that in those regions such matters were produced as could admit of alliance with the nobler substances of other regions, notwithstanding the cold and all the rigours of northern winter; which results would probably have been impossible, unless the planet had been violently treated in the way above described, and made patulous in various places, and so had received throughout its surface an insemination of fit materials.

And from these remarks it may further be concluded, that even the deluge was a proof of the Divine Providence, its effect being, that all that was hidden in the bowels of the earth, and all that the planet had gained by successive series of changes and multiplied events, in this manner should be made available to the use of mortals; which it seems could not have been the case had not the terraqueous globe been forced to submit to disruption, and to the oppression of the deluge.

The following is a brief Index to the subjects discussed in this volume of our subterranean and mineral kingdom, in which we treat of Copper.

DIVISION I. The mode of smelting copper at Fhalun.—Attempts to improve the process.—Facts regarding the precipitation of copper by iron.—The mode of smelting at the new copper mountain in Sweden.—At Garpenberg in Sweden.—At Schilau in Sweden.—At Cleva in Sweden.—At Loberg in Sweden.—At Rœraus, Tolgen, Faudahl, Quickne and Insett, Selba and Meldahl in Norway.—In Russia.—In England.—Among the Pyrenees.—At Agort.—At Pubel and Innspruck.—In Hungary.—At Cuttenburg in Bohemia.—At Eisleben and Mansfeldt.—In Saxony.—At Sangerhausen.—At Bergen, Wickerode, Ilmenau and Altenau.—At Grætslitz.—At Franckenberg.—At Andreasberg.—At Goslar.—In the Black Forest.—At Lauterberg.—At Stolberg, Strasburg, and Dresburg.—The purification of copper in Germany.—Of the copper of India, from Alphonso Barba.—Of copper, from Agricola.—From Rösler and Löhneis.—The mode of crude smelting.—Attempts at smelting copper according to Kellner.—According to another writer in a work entitled *Von Ertzbeitzen.*

THE SEPARATION OF SILVER FROM COPPER,—in Hungary.—At Cuttenburg.—At Hækstedt.—At Grundhal.—In the Black Forest.—At Andreasberg.—At Goslar.—According to Kellner.—From the author of *Von Neuen Zeigerung.*—According to Agricola.—According to various authors.

OF BRASS, AND ITS PREPARATION. First of the lapis calaminaris at Aix-la-Chapelle, in England, at Goslar, in Saxony, and other parts.—The preparation of brass in Sweden.—The mode of making brass in England.—The mode of converting copper into brass at Goslar.—Ditto at Grætslitz.—Furnaces for making Tyrolian brass into ochre.—The mode of converting copper into brass in other places.—Of bell-metal, treating of the mixture of copper with other metals and minerals, and first of the various mixtures of copper with other metals.—The casting of statues.—The casting of bells and cannon.—The founding of type. —The secret mode of one Elias Flicker, of Augsburg, for casting cannon.—The casting of cannon in France.—The brass of the ancients. —The mixture of metals for speculums.—Imitation gold, or Prince Rupert's metal.—Appendix, treating of zinc.—A white or silver-coloured metal, and the way of preparing it.—Methods of plating copper with silver, or of giving it the colour of silver.

Division II. gives the various modes of assaying copper ore and stone, and first treats of the different kinds of copper ore.—The different kinds of pyrites.—The assaying of mineral copper, treating of the crucibles and small furnaces, in which the assaying of such mineral for copper, is carried on.—The fluxes used in assaying copper.—The mode of assaying the minerals of copper that are easiest to melt or assay.—The mode of assaying those that are more difficult.—Of assaying meagre ores of copper.—Of assaying copper ore for copper stone or skiærsten. Another mode used by M. Erker of assaying copper ore for copper, or copper stone.—The mode of assaying copper stone for copper.—The assaying of impure or black copper for pure copper. —The assaying of copper by lapis lydius.—The assaying of copper or copper ore for silver.—The assaying of copper stone, scoriæ and ore for silver.—The mode of cutting off little knobs or portions of black copper suitable for the operation of assaying.—The assaying of copper for silver.—The assaying of impure, arsenical, antimonial metal, bell-metal, &c., for silver.—The method of assaying all kinds of money for silver.—The granulation of silver, pure and impure.—The method of assaying granulated silver for silver.—The method of assaying lead containing silver, for silver.—The preparation of touch needles.—The way of ascertaining whether there be copper in lead, and *vice versâ*.

Division III. exhibits various chemical preparations and experiments with copper and brass, and treats of the preparation of verdigris. —The process and the various modes of preparing ultramarine.—Burnt copper.—The preparation of crocus veneris.—Vitriol and crystals of copper.—Tinctures of ditto.—Spirits of ditto.—Oil of ditto.—Sulphur of ditto.—Flowers of ditto.—Different other chemical preparations of ditto.—Mercury of ditto.—Regulus of ditto.—The mixture distilled from regulus of antimony, copper and sublimate.—Alkahest of Zwelfer.—Quintessence of copper.—Green caustic of copper.—Ignis Veneris.—Ens primum Veneris.—Chemical purifications of copper.—

Glass of ditto.—Various observations on copper collected from different sources: the specific gravity of copper.—The increase of weight which copper undergoes when submitted to flame.—The solubility of copper in various acids.—Changes in colour in mixtures containing copper.

INDEX OF SUBJECTS.

Note.—In the following Index an attempt has been made, not merely to give an abstract of the ideas contained in the work, but also to present them in their orderly sequence, so that each article may afford a consecutive view of the author's opinion on the given subject. By a perusal of the Index, therefore, it is hoped that a tolerably correct idea may be obtained of the important matters treated of in The Principia, and a sufficient interest be awakened in the mind of the reader, to induce him to make a more complete acquaintance with the author, by a careful study of the work itself.—*E. R.*

Active, the, of the first finite, is that finite passing into local motion, I., 120. There is nothing substantial in the superficies formed by this active except the one circumfluent point, 124, 127, 182. The active by its local motion is equally efficient in every direction, 125. A single active cannot dispose the finites into any definite situation, 128. Many actives may be confluent in the same space without coming in contact, 128. Such confluent actives may adapt themselves to any angle, and form any figure, 129. If they are so abundant as to come into contact, they adapt themselves to fresh peripheries, 131. They are capable of occupying either a very large or a very small space, 131. The force of the actives increases with their number in any given space, 132. An active may be conceived to originate from the natural point, in all respects similar to the active of the first finite, but it is a purer and more universal fluent, 138. This active occupies the least spaces and fills all interstices, precluding a vacuum, and every where surrounding the elemental surfaces to preserve an equilibrium, 145. Under the greatest degree of compression the actives in the first element lose their force, 156. They are dispersed by the greatest degree of expansion, and the element is thus dissipated, 157. See *Element, first.*

Active, the, of the second finite, is that finite passing into local motion or liberty. It is therefore produced in a similar manner to the active of the first, I., 178. It pre-supposes a space in which the finites may effuse themselves, 179. All the attributes of the first active may be assigned to this or to any other, 179. The only difference between the first and the subsequent actives being that the latter describe larger circles and consequently move with less velocity, 179. The actives of the first and second finites may occupy the same space, and if they come into contact, the celerity of the first necessarily yields to the greater mass of the second, 180. Actives of the same kind always flow with the same velocity, and describe similar circles, 181.

The actives of the second and subsequent finites describe eccentric circles, 181. Actives have no determinate place unless they are inclosed by finites or elementaries, 183. Actives have no relation of upward and downward, and no weight; the largest in these respects being the same as the smallest. They cannot be said to resist, but only to act, 183. They cannot be called material, 184. The actives of the first and second, act with a greater force in conjunction than either could by themselves, 184. The solar ocean consists of these two actives, 185. See *Active of the third finite.*

Active, the, of the third finite, is that finite in a state of liberty, and is similar to the second active, as the second is to the first, 186. Its dimensions, and the circles it describes, are larger than those of the second, and its motion slower, 186. Its mass is also greater, and gives rise to an inertia somewhat similar to weight and resistance, 186. The actives of the third and second finites, may be simultaneously in the same space, but not together with those of the first, 188. Consequently by the perpetual influx of the first, the actives of the third finite are reduced to the nature of passives, and compose the surface of the second elementary particle, 188. See *Finite, third.*

Actives, the fourth, the fifth, &c. These actives, together with the first, second, and third, are perfectly similar except as to dimension, and consequently as to degrees and momenta, II., 312. The actives of the fourth finite cannot be in the same place with those of the second and first, nor the actives of the fifth with those of the third, second, or first, 314. The actives of the fourth and fifth finites act more strongly than if the space were only filled with actives of the fifth, 315. These actives are the finites themselves which constitute the surfaces of aërial and ethereal particles, running freely into eccentric circles and gyres, 315, 316. Their action upon the objects they meet is more impetuous than that of the actives of smaller dimension, 316. The actives of the fourth finite can form an active space only among the particles of ether, and those of the fifth likewise among the particles of air, 316, 317. The actives of the fifth may be in the same space, and in perfect freedom, with the first and second elementaries, 324. A space consisting of actives of a sixth finite may possibly exist and be enclosed by aqueous vapours. The actives of a seventh finite, however, appear to be incapable of forming a space within the elementary parts of our world, 328, 329. The actives from first to last are latent in a globule of water, 342.

Air. Air and water do not penetrate into the expanse of the vortex but occupy the proximate circuit of the earth. II., 145. In other worlds the air and ether may be differently modified, and thus not adapted to the organization of our senses, 246. The air is the fourth element of the world, and derives its origin from the fifth finite, 303. The finites occupy the surface of its particles, and within it are enclosed the first and second elementaries. It is similar to ether in all things except in dimensions, and consequently in degrees and moments, 304. Its particles are therefore constantly spherical and press equally in all directions, 305. A large volume of these elementaries may originate from a small volume of finites. The new earth continually decreases as to its surface, while the atmosphere around it is more perfectly formed, 306. The volume of aërial particles moves much more slowly and to a much smaller distance than the volume of ethereal particles, 309. The laws of the third element (see *Ether*) may be summarily applied to the element of air, 306—309. Whatever the ether presents to our organs by means of colours, the air presents to us by means of modulations and sounds, 310.

Aqueous Vapour. In the vapour of water all the mechanism and geometry of the higher elements are illustrated, II., 337, 338. The particle of vapour is formed on the surface of water and encloses within itself a small volume of ether; its surface, which is spherical, is equilibrated by the pressure of the circumfluent ether and air, 338. The particle of aqueous vapour is not perfectly elementary; it is nevertheless endowed with elementary qualities, and may be expanded or compressed according to the state of the enclosed ether and surrounding air, 339, 340. A large volume of vapour may arise from a small volume of water, and become more and more expanded by the application of heat. Its expansive force is so great that by it large weights may be lifted up and walls of iron and brass be burst asunder, 340. Particles of vapour interiorly contain only ether, while globules of water contain both ether and air. 341.

Author's, the, method I., 3, 70, 71, 211, 212, 315; II., 363. His laudatory mention of Muschenbroek, 249; II., 93; of David Gregory, II., 270. His perpetual recurrence to first principles, 301. His summary of the principles elucidated, 363—365. His motive, the simple love of truth, not the desire of applause, 265, 366. His obligations to Christian Wolff, 366.

Cause, a, always exists in its effects, I., 46; and every effect is the cause or means of producing a new series, 78. There is a connection of mediate causes from the first simple to the last composite, 79. These causes are contained in one and the same ovum or point, and are derived into successive finites continuously by similitude, 80. The cause of all being and existence is motion, 103. Effects cannot be varied without a variation in the causes, 207, II., 242. No cause can bring anything into act except by means of contingents, 242.

Chaos, the, once existing, consisted of primitive forces and elements flowing in a vortex round the sun, in which were latent the origins of all mundane things, II., 251—257. This vortex or chaos was formed by the compression of the second element, originating a passive boundary of fourth finites round the solar space, 258. The volume of this chaos continued to increase by the successive compression of the second elementaries, forming an incrustation round the sun, and completing its vortex, 259. This incrustation or chaos being formed in motion, continued to gyrate round its active centre, 260. Its motion may be compared to that of the effluvia about the magnet, 261. The whole of this immense crust, together with the enclosed solar space, is similar to an elementary particle, 261. In consequence of its centrifugal force it recedes farther and farther from the sun, and becoming attenuated as it gradually expands into a larger circle, can at length no longer cohere, 261, 262, 264. In consequence of the disruption which ensues, a passage is afforded to the vortical element, which rushes in so as to act upon all sides, 264. By collapsing upon itself towards the equators, the crustaceous expanse forms at length a broad belt around the sun, gyrating in a similar manner, until, by further attenuation it bursts, and its parts glomerate into planets and satellites of various dimensions, 262, 267; see *Planets*. This philosophy confirmed by the observations of astronomers as to the appearance and disappearance of stars, 270—272. Some stars are unable to perfect any vortex around themselves owing to the proximity of numerous other systems, 272.

Composite. Things composite originate from things simple, I., 47. Hence they consist of aggregations of the first substantial or simple finite, 74. And produce by frequent modification all the varieties and degrees of perfection, 76. The more numerous are the composites of which any finite or active consists, the greater is the eccentricity of their surfaces, 182.

Connexion. There exists a continual connexion between the soul and the body, I., 1. There is a connexion by mediums from ultimate to ultimate, 20. Contiguity is necessary to the production of every operation, 20, 33. All things both such as are necessary and such as are contingent, must necessarily have a connexion with their first substantial principle, or no reason can be assigned for any phenomena, 21, 23. To know, *à priori*, the nature of the connexion between causes and their causates, is not within the province of man or of geometry, 27. The connexion of the particles of an elementary volume is according to the parallelism of their poles, 159. It is at the poles principally, that the parts are in contact; at the equators the contact is only in one and the smallest point, 160. Mechanical strength depends on the contiguity and connexion of parts, 366. In consequence of the solar vortices being in series and connexion, no change can happen in one, which is not perceived in all the others, II., 238. The subsistence and perfection of the world depends on its connexion with first principles, 244. There is nothing contiguous or resisting within the first and second elements, 280. The connectives of bodies are more or less subtile and crass, and cannot be dissolved by actives of the same kind, 326. The connexion from the first principle, to the ultimate of nature, may be seen in the microcosm of an aqueous bubble, 342, 343.

Corpuscles, magnetic. Corpuscles of every form are magnetic; provided the elementary magnetic particles can pass through their pores, and connectives of their structure, and do not open wide enough for the particles of a grosser element. The magnetic substance itself is ferreous, I., 222. Of this kind are the smallest corpuscles, or effluvia, proceeding from magnets and iron, 222, 239. Such corpuscles, or effluvia, emanating from all hard bodies, are penetrated and rendered pervious only by the most subtile elementary parts, and this too, in the direction of a right line, 223, 226. Were the arrangement of the foramina not rectilinear, but inflected at various angles they could not possibly be magnetic, 223, 225, 226. Effluvia or corpuscles of this kind, when nothing obstructs, constitute active centres and form around themselves spiral gyrations or vorticles, 223, 225. See *Element, Motion.* Bodies are wholly magnetical when their corpuscles are situated in right lines or regular curves, 225, 226. The effluvia [corpuscles] of iron and the effluvia of the magnet have a tendency to coalesce into one sphere, 239, 240, 284—286. See *Electricity.*

Declination of the Magnet, calculations of the. Calculations for London in the year 1722, with an example of the method employed, worked at length, II., 156—166. Calculations for various years at London and Paris, 166—206. Declinations at Paris for every year, from the year 1610 to 1920. The annual progression of the declinations is inconstant, at one time passing through an entire degree, at another through scarcely a single minute, 210. The results of the calculus and actual experience may sometimes differ on account of various contingencies in making experiments, 211. The declination at several places calculated for various years, 211—225. See *Needle, magnetic.*

Dip of the Needle: see *Declination of the Magnet.*

Earth. See *Planets.* When first born of chaos, the earth was homogeneous and uniform throughout, its surface unclothed with any living vesture, II., 275, 276. The fourth finites, of which the infant earth wholly consisted, could not form themselves into larger finites, except near the surface, and even here they could not possibly become active, being pressed by the vortical element of the sun, 276, 277. By the formation of an ethereal sphere (see *Ether*) around the earth, its surface became considerably diminished, 278. The axillary motion which the earth possessed in common with its elementary particles, was participated by the ether, 278.

The earth, while it was yet clad with a vestment of ether only, remained simple and uniform, 299, 300. It next received an aërial vestment, 311, 330. The central globe of the earth is occupied by the fourth finites, which constitute the surfaces of the particles of ether, 316, 328. If these were liberated, the present equilibrium of the earth would be considerably modified, 328. The earth continuing its course from the sun towards its final orbit, surrounded itself with water, 330, 331, 332. By the dissolution of the parts in the water, and the emergence of finites, a crust became gradually formed on the surface, and was continually increased by an addition of parts one under another, 356, 379. Innumerable changes succeeded each other, before the earth reached its final destination and became enriched with so many entities as might supply the mineral, vegetable, and animal kingdoms with their treasures, 356—358. The earth, in its early ages, revolved about the sun more rapidly, and measured out shorter days and years. Its whole surface was surrounded with one perpetual spring, most highly adapted to generation and the procreation of animal and vegetable life, 358—362. The dense crust of the earth was broken up by the subjacent waters, and all that the planet had gained by successive series of changes, made available to the use of mortals, 381.

Earth, progression of the. The motion of the earth towards its orbit in the solar vortex, is governed by the spiral fluxion of the vortical element, and its own relative density, II., 345. The axillary motion of the earth commenced at the moment when it left the sun, and decreased in celerity as it progressed to its orbit, 346. The earth, like a large active, has a tendency to a second motion; still it is carried round the sun principally by the stream of the solar vortex, 346, 347. Moving among the elementary particles, it formed, like the small magnetic corpuscle, a vortex around itself, 347. See *Tellurian vortex.* The progressive motion from the sun diminishes in a simple ratio as to the spiral gyres, but in a duplicate ratio as to the diameter, 349. The velocities in the solar vortex are in the diameter, in the subduplicate ratio of the distances from the ultimate periphery, 350. See calculations of the proportional velocities and forces of two planetary bodies in motion in the solar vortex, 351, 353. The earth underwent innumerable changes during its progression from the sun, both as to its surface and the surrounding elements, 356—358.

Ecliptic: see *Poles.*

Effluvium: see *Corpuscles.* There are effluvia of innumerable kinds proceeding from all bodies, I., 245. Iron and all other metals abound in interior spaces, in which flow effluvia with vorticles similar to those which are fluent without, 288. Mere effluvia cannot of themselves present any magnetism, 315. See Experiments and Opinions of Muschenbroek, 315, 331. The effluvia of the magnet consists of the similar and smallest parts of iron, creating a regular sphere around it, II., 94. There are corpuscles which resemble a species of effluvia so small as to move only the volume of ether, not of the air, 296. See *Electricity, Phosphoric Light, Light.*

Electricity, arises from the gyration of certain minute corpuscles, excited by the tremulation of the parts of the hard body in which they reside, II., 296. Such gyrations are communicated to the ether, inclosed in the body as well as to that which is fluent without, 297, 299. This motion or tremulation diffused to a distance in the form of a gyre, enters into the texture of adjacent bodies and draws them into its current, presenting to the eye a play of phenomena similar to that of magnetism, 298. Electricity, therefore, consists in the motion of the third element or ether, which is less subtile than the second or magnetic element, 298. The longer a body can tremulate and the more it abounds with subtile effluvia by which the ether is put in motion, the more perfect are the electric phenomena; either of these conditions being wanting, no electricity can be produced, 299. The space consisting solely of actives of the fourth finite, and enclosed by the ethereal volume, by its passage through the atmosphere constitutes lightning, which is therefore identical with the electric fluid, 327. This elementary fire penetrates and dissolves the hardest bodies, and lays open the more subtile connections, by which the soul unites itself to the body, 327, 328.

Element, first. Before any element can exist there must be two principles, an active and a passive, I., 140. By means of which it is connected with the first substantial, from which these principles are derived, 142, 168. The first element possesses a perfectly yielding and elastic superficies, 143, 146—148, 158. The actives occupy its centre and the passives its circumference, 143 ; II., 279. Because the surface of this element lies between two equal forces, neither weight nor resistance can be predicated of it, I., 150. The finites which constitute its surface are in contiguity according to their poles, and are thus disposed into a spiral figure, 151. The change of state or motion in one, causes a similar change in the whole, 152. The close connexion of these finites and the want of space among the elementary particles prevent them from becoming actives, 153. The first element is a spherical molecule, 154. The finites forming its surface may flow in a single, double, or triple order according to the degree of compression, 155. In this state a fluxion takes place, in the figure of a cone, from each pole to the centre, 155. In the greatest degree of compression the elementary particle changes into a new finite, 156. It is dissipated by the greatest degree of expansion, 157. The elementary molecules flow most naturally into a vortical motion, 161, 212. They fill the whole space of the starry heavens, and form our solar vortex, 163, 168. In the particles of this element the pre-existing points and the antecedent finites are all latent, 168. In every elementary particle there is an axillary, a progressive, and a local motion, which remain the same in every state of expansion or contraction, 174. Their mobility also continues the same, 175. They can only be conjoined at their poles, 175. Every particle in any elementary volume contributes to the motion and figure of the whole, 214. The fluency of the elements in the vorticle of a magnet is the same as in a vortex, II., 232. Its particles are not exactly spherical, but have poles and polar cones, 279. See *Actives*.

Element, the second or magnetic, consists of third finites and the actives of the second and first, I., 196. The actives occupy its internal space, and the finites its superficies, 196 ; II., 279. It differs from the first element in regard to its greater dimension, I., 196. The centre of gravity being in some part of the surface approaches nearer to the centre according to the degree of compression, 197. These elementary particles, like those of the first element are perfectly elastic, 197, 213. And by virtue of their inherent force spontaneously conspire to the vortical motion, 197, 198, 212. The surface of this element is in equilibrium between two forces, 198. The first and second elementary particles flow concordantly into one volume, sphere, and vortex, 198. The pressure of the incumbent particles is according to their altitude in the plane of the zodiac, and to their area, 199. The finites which compose the surface of this element are passive, and similar in figure and situation to the finites of the first, 199. Their convex and lighter parts are turned to their interior space, they are thus compelled to cohere as to their poles, 199. The motion and essentials of the parts and the entire volume are similar in all the elements, 200. When the elements are formed into a vortex in which all the particles are compressed according to the ratio of the distances no further compression takes place, 201. All the pre-existing finites and actives concur in composing the magnetic element, 201. It presents the first series of sensuous phenomena, 211. Its particles are contiguous but perfectly yielding, 213. The poles and also the equators of all the parts in the elementary volume are parallel, according to the figure and situation of which the motion of the volume is modified, and flows vortically, 214, 215. All magnetic force consists in motion, proceeding spirally from a centre, until it comes to a state of rest in the rectilinear situation of the elementary particles, 217. Unless the arrangement of the foramina of the elementary particles were rectilinear, they could not be magnetic, 223. See *Corpuscles.* The greater the quantity of effluvia flowing round a magnet, the greater is the number of centres and vorticles, and the more closely they may be conjoined, 225. The magnetic sphere and its vorticles is a type and effigy of the starry heavens, 232. The situation of the elementary particles in the magnetic sphere is conformable to its figure, 232. The magnetic element freely permeates the interstices of every succeeding and grosser element, 312. The magnetic element regards the iron with which it associates, as its pole or centre, II., 64. The particles of the magnetic element are of two kinds, smaller and larger; the smaller subsist by a pure natural mechanism, the larger constitute the magnetic spheres, 144. This element exists in the solar vortex or that of our universe, and enters into the vortices of the planets, 145. The nexus of its particles from one pole of our earth to the other, produces a regular situation at any given place, analogous to its distance from the pole, 149. See *Pressure.* In consequence of compression near the solar active space, the particles of this element so compressed cease to be active, and thus constitute the fourth finite, 258. They are not exactly spherical, having poles or polar cones, 279.

Ens. There is a first ens originating from the Infinite, I., 46. This ens is the seed of all finite things, 53. The first ens susceptible of modification is the first finite, 99. The first ens is most simple and most perfect, 170.

Equilibrium, is the means by which two things in motion can be kept in perpetual conjunction, I., 144. On its force the perpetual preservation of situation and figure depends, 144. Equilibrium itself consists in an equal pressure on both sides of a superficies, &c., 144. It commences with the first element of the world, 144. There is no equilibrium without the conjunction and harmony of motions, 234.

Ether, the, or third element, originates from the fourth finite by its convolution into new particles, interiorly containing a small volume of the first element, II., 277, 279. It is formed near the surface of the infant earth, and participates in its axillary motion, 277, 278. The particles of ether are much larger than the first and second elementaries, and are exactly spherical, 279. Each particle contains as many active spaces as elementary molecules, 279. It differs therefore from the first or second elements in the contiguity and resistance of its interior parts, 280. The ethereal element is in perpetual motion, and the enclosed particles are more expanded towards the centre than towards the surface, and this in proportion to the intensity of the motion, 280. It is preserved in equilibrium by interior and exterior forces, 281. The figure of its surface and its elasticity are owing to the enclosed particles, 281, 282. The ethereal element expands and offers more resistance in proportion to the celerity of its motion; while the first and second elements become more compressed by motion, with the same result, 282. By extreme motion or compression, the particles of ether become rigid, 283. They are more rigid at their poles than equators, 283. The particles are more or less elastic according to their degree of expansion or compression, provided neither of these be produced by motion, 284, 285. Causes of expansion may exist which may cause disruption of some of the particles,

285. The fourth finites constituting their surfaces extend by continual spires from one polar point to its opposite, causing a tendency to perpetual central motion, 286. The surface of an ethereal particle may be doubled, tripled, or multiplied in various ways within, and the interior space be thus filled with ethereal bullules, which cause an increase of hardness towards the centre, 287, 288, 292—294. The ethereal bullules are in the state of expansion of the ethereal particle, and in like manner the elasticity of a volume is as the elasticity of a particle, 288, 289. See *Ratio*. Their mutual pressure on all sides is according to the altitude or weight of the incumbent volume; they also exercise a similar pressure upon the interior parts of any hard body whose texture they are able to permeate, 289. They preserve a perfectly spherical figure in every state of motion or compression, 290. The equilibrium in a volume is both particular and general, 291. The phenomena of ether are those exhibited near the earth in heat, light, and electricity, 296—299, which see. Whatever the eye perceives in the ether, of this the ear is percipient in the air, 309.

EXPERIENCE. Experience may be defined to be the knowledge of every thing in the world of nature which is capable of being received through the medium of the senses, I., 4. Experience is not wisdom but only the medium which leads to it, 12. We can learn nothing from experience concerning the natural point, 67. Experience is first afforded by a volume of elementary particles, in which the phenomena can be mechanically represented, as in the second or magnetic element, 93. Unless there is a mechanical connexion between first principles and actual experiments, the former are mere hallucinations, 315.

FIGURE and space are attributes of motion, I., 53. Figure cannot be predicated of the natural point except simply and by analogy, 60. The most perfect figure is the perpetually circular or spiral, 63. This is the figure of conatus, 66. Figure, and its producing motion, and conatus are exactly correspondent, 60. The more figures are compounded the more they are varied, and the more dissimilar they become, 76. All varieties of figure are produced by varieties of motion, 77. The figure of the simple finite accords with the motion of the points among themselves, 80. With this figure the axillary motion of the centre of gravity also coincides, 90. A perfectly uniform figure can be produced only by a regular and similar motion, 22. The more figure becomes modified, the farther it recedes from perfection, 99. Motion supposes direction and consequently figure, 103. The preservation of figure depends upon equilibration, 149. A variety of figures and forces may be formed by the continual eccentricity of the second active, 182. Every particle in a volume contributes to the general figure, 214. Figures which are not perfectly geometrical are liable to suffer from various contingencies, 366. The figure of the ethereal element depends upon the contiguous arrangement of the enclosed particles, II., 280.

FINITE: see *Natural Point*. The first finite is the first substantial of the natural world, 72. It is originated by motion among the points, 72, 73, 80. Hence it is also the least substantial, and being the least is indeed the only substantial or that of which all composites are the aggregates, 74. It is a geometrical figure with the fewest boundaries, 75. It therefore occupies space, 75. It is the most perfect of all figures, 75. The producing force, or motion, in this finite corresponds to the conatus of the natural point, 78, 79. And exists anew in every sequent, 79. This finite is the first limitation of natural substance, 81. It is a geometrical minimal and with respect to things compounded is almost nothing, 81. In every finite there are two poles formed by the spiral motion of its parts, 85. And consequently an equator with meridians and lesser circles, 86. In this respect the microcosm resembles the macrocosm, 86. The finite also revolves about its polar axis, 86. In addition to which it has a progressive motion of all its parts, 88, 173. The centre of gravity is not in the middle of the corpuscle, but near the middle, where the greatest activity exists, 90, 172. It is therefore perpetually impelling the corpuscle to an extraneous and circular motion, 91. The series and abundance of these smallest substantials is so great that one is in contact with the other, 97. For any new finite to be created there must be a motion of the antecedent finites one amongst the other, 105. Such a motion, when the finites are in contact, produces the second finite, 97, which is the first passive, 118. When they are not in contact, but dissociated and dispersed, it produces the co-existent of the second finite or first active, 97, 118. See *Finite, second.*

Finite, the second, originates from the first, but is comprehended in more numerous and larger terminations, I., 96. It is generated by motion, 97. Without the contact and mutual pressure of the series of first finites it could not be produced. 97. The second finite is geometrically divisible into first substantials, 98. It is another geometrical ens, similar in figure to the first substantial, but less perfect, 99. The situation, progression and centre of gravity are also similar, 101. But the celerity is less, 101. This finite in regard to substance is the second boundary, 101. The connexion of the second finite with the first is in all respects similar to that of the first with the natural point, 116. There is thus a connexion between the natural point and the second finite through the intermediate or simple finite, and consequently a power in the second of producing subsequent finites, 117. The second finite is a passive ens, 119, 126. Its co-existent is the active of the first finite, 119, 132. These together constitute the first element, 143. See *Active, first.*

Finite, the third, or substantial differs from the preceding finites only in dimensions and celerity, I., 191. It consists of second finites, and is consequently nothing but the point raised to its third power, 191. It originates from the great compression of the first elementary particles near the large active or solar space, 192. It has the power of giving birth to new finites, 193. See *Element, second or magnetic.*

Finite, the fourth, is similar to the third as the third is to the second, &c., differing only in dimensions, consequently in degrees and moments, II., 249, 250. It arises from the second elementary particle as the third from the first, consequently near the active solar space, 250, 258. The whole solar and planetary chaos consisted originally of these fourth finites, 250. See *Chaos.* These finites, by convolution into new particles, originate the third element or ether, 277.

Finite, the fifth, originates from the fourth, and is similar to it in all things, but in its dimensions, II., 302. It has its origin where the finites of the fourth genus can unfold and mutually finite themselves, consequently at some distance from the sun, near the earth's surface, 302. These new finites constitute the surface of a particle of air and supply fire with its element, 302. See *Air, Fire.* The fifth finites cannot become active unless they are set free from their surfaces, when they immediately relapse into the surfaces of the adjacent particles of air, 316.

Fire. The actives of the fourth finite create subtile elementary fire : those of the fifth, the common culinary or atmospherical fire, II., 312. The spaces occupied by these actives cannot subsist unless they are continually supplied with fresh quantities of their respective actives, 317, 318, 326, 327. The finites of the fifth order, which enter largely into the compages of various combustible bodies, and which also form the surfaces of the aërial particles, rush out into a wider space, when the textural connexions of these bodies are dissolved, and become actives ; the adjacent aërial particles also flow in, and being set free, the finites occupying their surface become actives, which give increase and force to the highly-excited space, 318—320. The actives immediately relapse into the surfaces of other finites. See *Finite, fifth.* In this process, the active forces of nature are liberated from vegetable and mineral bodies, and the circle of her life renewed, 320. The particles of air nearest the igneous space are in the highest degree of motion and consequently in the highest and most rigid state of expansion, 321. A similar law obtains with regard to the ether round a space consisting of actives of the fourth finite, 321, 322. When the central motion of the aërial particles is not sufficiently intense to excite a motion in a volume of ether, no light is produced, 322. The light exhibited by common fire arises from the motion of the ethereal particles or fourth finites excited to activity by the actives of the fifth finite; these two being capable of acting in the same space and increasing its activity, 323, 324. The force of the active space increases in proportion to the abundance of its actives, 325. The space consisting of actives of the fifth finite has no weight or situation except what is given it by the volume of ether and first and second elementaries, 325. The texture of bodies is dissolved by the actives, and by the ethereal particles, in a state of intense motion in the igneous space, 325, 326.

Forces, the centripetal and centrifugal, result from the spiral action of the solar vortex, II., 345. See *Motion, Magnetic Forces, laws of.*

Geometry. Under the empire of geometry we may rank the whole elemental kingdom as well as the mineral, vegetable, and animal, I., 3. The second medium leading to wisdom, by which the arcana of invisible nature may be unlocked and revealed, is geometry and rational philosophy, 14. Geometry is conversant only with things that are finite and have limits, and with the figures and spaces thence originating, 25. It acknowledges a simple point as the first ens of its existence, and thus seeks for its origin out of itself, 49. It is the law and essential attribute of every individual substance in the world, 51, 207. Geometry and the world both proceed from the same point, 51. The laws of geometry are incipient in conatus, 65. Because the figure of the motion into which conatus flows is spiral, 66. Nothing can be geometrical without limits; geometry therefore, actually begins with the first finite, 75. Which finite is the geometrical minimal, 81. The second finite is the second boundary of substance, but geometry requires at least three boundaries before it can determine anything by analysis, 102. The skilful geometrician, from given ellipses or planetary orbits, may infer the incurvation of the axis of the solar vortex; also, the situation of the neighbouring vortices and other particulars, II., 238. Geometry and mechanism, as to first principles and motive forces, are similar in every mundane system, diversity existing only in the series in respect to degrees, ratios, and figures, 245, 246.

Gravity. The centre of gravity is not in the polar axis, but rotates about it, I., 90, 122, 172. It is formed by a continuous and perfectly regular motion, 105. And being the centre of such motion it is its living and sustaining force, 106. The centre of gravity, (in the elementary particle), is in the plane of the ecliptic, not in that of the equator, 122. It is therefore in the surface of the corpuscle, 174. Its motion accords with the axillary motion, 123, 174. It approaches nearer to the centre in proportion to the degree of compression, 197.

Heat. The central motion of a particle of ether causes heat, II., 296, 322. If this motion be urged from the centre to the circumference it causes light together with heat, 296.

Ignis Fatuus: see *Phosphoric Light.*

INFINITE. The Infinite is the cause and origin of the finite world and universe, I., 25 ; II., 229. The Infinite and Only Begotten became man, that he might restore the connexion between the world and Himself, I., 45. In the Infinite there is no relation of greater or less, but all things are in simultaneous order, II., 229. All the heavens, however multitudinous, however vast, yet being but finite, and consequently having their bounds, do not amount to a point in comparison with the Infinite, 238, 239.

IRON is universally present in the mineral kingdom, I., 222, 223. The pores of its smallest parts, or of the effluvia, are formed in accordance with the parts of the magnetic element, that is to say, they are rectilinear, 223. The effluvia of iron or steel, therefore, is for the most part magnetical ; but not unless the vorticles interiorly are reduced and disposed into a regular situation, 239. The regular texture, and consequently the magnetism, of iron, may be destroyed by the hammer, the heat of the furnace, &c., 239. By the application of the magnet, it may be disposed into a regular situation, and become magnetical, 240—242, 283, 284. In regard to the mass and thickness of iron, there is a maximum and minimum, upon which the magnet exercises its greatest force, 288, 289. The disturbance of the particles in iron, highly heated, obstructs the magnetic current, 289. The communication of magnetism consists simply in an arrangement of the parts, 314 ; II., 72, 93. Iron therefore cannot acquire by friction against a magnet any augmentation of weight, 314. The magnetic parts which are in iron are, by means of friction with the magnet, disposed into a regular situation, and a magnetic sphere is thus formed around the iron, 362—364. When only some of their parts are reduced to this arrangement, the iron becomes only slightly magnetical, 364. When, however, they are once reduced into a perfectly regular disposition, they cannot by reiterated friction be made more regular, and consequently the magnetism of the iron cannot be rendered stronger, 365. In order to obtain the greatest possible effect, the iron should be of a certain relative magnitude, and perfectly geometrical in figure and structure, 365, 367. See Experiments, 367—380. The effluvia emitted from iron extends its sphere to a considerable distance, and its vorticles radiating in all directions, dispose the magnetic element into the same situation ; the latter therefore regards the iron as its pole, from which the vorticles issue in a lengthened series, II., 64, 65. The situation of the smallest parts within iron, not magnetic, is irregular, 64. Iron may be rendered magnetic by other modes besides the friction of the loadstone, viz., by the continual action of the magnetic element ; by stretching, bending, hammering, &c., 72—74. See Experiments, 75—92.

LIGHT. Motion diffused from a given centre through the contiguous particles of an ethereal volume produces light. When the ethereal particles pass freely and regularly through any hard body, such body is diaphanous or pellucid ; if the current of motion is irregular, the body is semi-pellucid or white : where the ether cannot penetrate, it is reflected at a certain angle, 295. This light will be accompanied with heat if there is a central circumvolution of every particle; but it will be without heat if there is only a local motion of the ethereal particles amongst each other, II., 296. The visual representation of objects consists in the reflection of ether from innumerable centres, 297. Corpuscles, or effluvia, which are so small as to move a volume of ether, but not of air when moving spontaneously, excite a cold light to a certain distance. If such corpuscles are put in motion by the tremulation of the parts in any hard body in which they reside, both light and electricity are produced, 296.

LIGHTNING. See *Electricity.*

MAGNET. The effluvium exhaling from the polar extremities of a magnet surrounds the mass, and thus connects the poles by a kind of sphere, I., 227. The axes of the magnetic vorticles conform to the curvature of this sphere, 228, 229. There is no need for the continual renovation of the magnetic sphere, 229, 314. The magnet and its sphere are inseparable, the former being subject to every change in the latter, 229, 230. This sphere, not the magnet itself, forms the polar axis on each side, 230. The sphere, and consequently the situation of the poles, conforms to the figure of the magnet, 230. The effluvia of the magnet coalesce with the effluvia of iron, and thus produce a more powerful sphere, 239, 240. There is no one magnet absolutely similar to another, either as to its interior texture or as to the figure of its circumambient sphere, 244, 245. Several poles may exist in one magnet, 244. If there is no constant ratio between the conjunctive forces of two magnets, it is because no two magnets are similar, nor is any magnetic sphere at all times similar to itself, 248. See *Magnetic Forces, laws of.* The magnet does not act upon iron at the same distance as two magnets act upon each other, 299. In the communication of magnetism to iron, the magnet loses none of its force, 314. Its forces may be destroyed by the application of heat, 232. By means of chemical operations on the magnet, nothing more can be elicited than that it may consist of parts of a diversified nature, but that the magnetic virtue and quality reside only in the iron particles, 333, 334. By comminution of the magnet into dust, the magnetic quality becomes confounded, 335. The iron or magnetic effluvia may be prevented from exhaling, by implication with certain salts; when they can only be liberated by fire or some chemical expedient, 335, 336. See Experiments, 336—361. The effect produced upon iron by the magnet will be greatest when the former bears a certain adequate proportion to the latter, 365. One magnet may consociate with itself several pieces of iron, II., 1. There can be no two magnets [loadstones] absolutely similar to each other as to their conjunctive force, 1, 2. See Experiments, 2—63. In every magnet there are two forces, the tendency to conjunction, or attractive force ; and the tendency to a parallelism with the magnetic element as seen in the mariner's needle, 67. The magnet is governed by a certain element, see *Element, magnetic*, and obeys the motion and situation of its particles, 144, 148. In the magnet and its sphere there is a type and effigy of the heavens, 231.

MAGNETIC FORCES, laws of. All magnetic force consists in motion, I., 217, 365. See *Element, magnetic.* Magnetism depends on the regularity and permeability of the corpuscles, 223, 226. See *Corpuscles.* The more regular the situation of the corpuscles and the greater their quantity, both within and without the mass, the closer is their conjunction and the stronger the magnetism, 226. The colligation of the magnetic effluvia, viz., of the corpuscles and their vorticles, is closer at a less than at a greater distance from the magnetic mass, 227. They form a sphere surrounding the magnet, conforming to its figure and connecting the polar extremities, 227, 230. This sphere forms a pole or polar axis where the vorticles begin to incurvate their course, 230. All the vorticles which are colligated together proceed at first according to this axis in a right line from the magnet, and then deflect themselves from the axis in every direction, 230, 231. These vorticles are concentric when the axes of their elements are rectilinear, and more or less eccentric in proportion as they are incurvated, 232. By the application of two or more magnetic spheres, the figure of each is immediately changed, and one larger sphere is formed: the whole spatial distance between them also becomes an axis, 234. The larger sphere is differently configurated according to the various application of the spheres of which it is composed, 236. The more closely the magnets are applied to each other, the more firmly the vorticles of their spheres are colligated, 234—236. The direct conjunction at the axis is the strongest and closest, 238. If the effluvia of iron and the effluvia of the magnet coalesce into one sphere, the iron and the magnet are conjoined in proportion as the former is surrounded or penetrated by the common sphere, 240. The attractive force between two or more magnets depends not only on the axis but upon the whole circumambient sphere, 246. This force is stronger at a less distance, and ceases where the spires of the vorticles are incident to each other at an angle of 45°—246, 247. (This law does not apply to the action of the magnet upon the needle, 248.) See Experiments, 249—260. In magnets perfectly similar there is always a constant geometrical ratio between the attractive forces and the distances, 248. The magnetic force and the sphere about the opposite poles of any magnet are dissimilar, 261, 262. See Experiments, 262—264. When two or more magnets are applied to each other equatorially, their spheres combine and form an axis between the poles, 265. In this case the conjunctive force is less than when the magnets are conjoined by the application of their axes or poles, 267. See Experiments, 267, 269. If the cognominal poles of two or more magnets be applied to each other, their spheres will coalesce into one larger sphere, 270. In the middle space between the magnets thus applied, the vorticles repel each other, but towards the sides of the sphere they flow in one and the same current, 270—274. When the cognominal or inimical poles are thus applied, the magnets are partly repelled and partly attracted, and their repulsive force is increased according to the distances and ratio of the spheres, 274—276. See Experiments, 277—282. The attractive force between the magnet and iron is greater than between the cognominal poles of two magnets, 286. The magnet exercises the greatest force upon iron of a given proportion, 287—289. See Experiments, 289—307. The magnet acts with less force upon iron red hot than upon cold iron, and its force decreases according to the degree of heat, 308. See Experiments, 309—311. Magnetic attraction is augmented by a larger quantity of emanating effluvia, 314. The magnetic force invests iron according to the regularity of its figure and structure, as well as the relative magnitude of its mass, 367. See Experiments, 368—380. The conjunctive force of the magnet [loadstone] may be increased by the application of an iron armature, II., 1. See Experiments, 2—63. Innumerable spheres, whether pertaining to the magnet or iron, may exist within one and the same sphere, and each sphere may operate according to the situation and motion of its parts, 66, 67. See *Sphere*.

MAN. Man is introduced into the world and its mechanical order as an intermediate between its least and greatest things, II., 230. The whole of what exists is not comprehended within the sphere of his observation, 230. He is endowed with an upright mien that he may look upward, and with a soul derived from the aura of a purer and better world, in virtue of which he is allied to heaven, 231, 362. The highest wisdom of man consists in a proper knowledge of his relation to the Infinite, 247. He was created into all the harmony of the visible world and introduced into its paradise, that he might enjoy the charms and varieties of nature, and learn wisdom in order that he might know how to reverence, love and worship the infinitely-wise God, 362.

MECHANICS. Mechanism is conceived and born of the elemental kingdom. It is the law of nature herself as she acts and moves in the elements, I., 3, 15. The mechanism of the world consists in contiguity and connexion, 20. The highest mechanical capability is exhibited in the fluxion of the spiral, 83, 94. It is in the analysis of the second finite that we first receive assistance from mechanical laws, 105. Deductions *à priori* must be confirmed by mechanics, 105. The potency of mechanics is seen in the lever, its motion in the inclined plane, and both in the spiral, 105. There is a mechanical, geometrical, and physical necessity for the situation and motion of all elementaries and finites, 176. Mechanism is geometry in action, 207. The first principles of mechanism are the same in all worlds, but variously modified, II., 246.

MERIDIAN. The meridian passing through the north magnetic pole in the year 1720 was distant from the meridian of London 112° westward, and that of the south magnetic pole, 145° 30′.

MILKY WAY : see *Sphere.*

MINERAL KINGDOM, the, is an effigy of the changes which took place at the formation of the earth, II., 242. It contains the origin, root, and essence of the variety which obtains in the vegetable kingdom, and through that of the animal kingdom, 243. A volume of water is mechanically similar to that of a mineral of any kind melted into a liquid, 335. Vegetables and minerals were generated in the material crust which covered the primeval ocean, 355. There is so close a connexion and affinity between all kinds of metals, and likewise between sulphurs, salts, and stones, that the quality and texture of the one cannot be discovered or thoroughly seen without a simultaneous view of the others also, 373. Metals may be generated, may grow to perfection and maturity in cold climates as well as in hot, 378.

MODE. Nothing can exist without a mode, I., 49. Modification commences with the first finite or substantial, 96. The more any entity is modified, the further it recedes from essential perfection, 99. A world abounding in objects and phenomena can be perfected only by modes or modifications, II., 242. Changes and contingencies may be infinite, as also the varieties of modifications, 245.

MOTION is the cause of all modification, I., 49, and of all existence, 49, 62, 77. Pure or total motion is independent of substance, 53, 57. It is the immediate production of the Infinite, 54. It cannot be considered geometrically, but rationally, 55. Because it cannot exist in space, or among finites, except as a centre, or conatus, 64. Motion is the source of all contingency and limit, 49, 77. Finite motion supposes something substantial as its base, 55. Pure motion consists in internal state or conatus, 57. The internal motion of the natural point tends to the perpetually circular, or spiral, 63. Whence arises an axillary motion, afterwards a progressive rotatory motion, and lastly a local motion, tending to perpetual surfaces, 66, 173. Motion itself is not substantial, but produces an appearance of substance and form, (illustrated by the fluxion of the geometrical point,) 68. Motion among the natural points as well as in the point itself is spiral, 73, 82. This motion originates the first finite or substantial, 77. Without motion there can be neither centre nor circumference, nor any coherence of parts, 77. Internal motion is the only producing power, 79. Spiral motion to be continual must be reciprocal, 84. By motion the parts tend to equilibrium, 85. The regular communication and reciprocation of the spiral motion is obtained by means of two poles, 85, 121. The conatus arising from the regular situation of the parts in a spiral figure tends to an axillary motion of the whole, 86, 122. Also to a progressive motion of the parts and spires, which is slower than the axillary, 88, and likewise to a second or local motion, 92. The progression of the spiral motion is retarded in a simple ratio by the resistance of the fluent points, 107. The axillary, progressive, and local motion, in a simple or point, can be investigated only in the same way as an unknown quantity in algebra, 120. The progressive motion of the spiral in the plane of the ecliptic forms a superficics, 123. Motion always originates in a more subtile element than that in which its activity is manifest, 136, 137. Situation and figure exist potentially in differing motions; but not in actuality until an equilibrium is established, 144. The elementary particles naturally flow into a vortical motion if there be an active centre round which they can gyrate, 212. All motion in an elementary volume flows from a certain centre, and to a greater or less distance according to the force of the centre, and the contiguity, elasticity, and yieldance of the parts, 213. Every particle in an elementary volume contributes its share to the general motion, 214. The spiral or vortical motion is the necessary result of the combined forces of polar and equatorial motion, 215. The whole motion in a vorticle is according to the situation of its axis, 232. Motion slackens according to distance and the resistance of contiguous entities, 365. A common motion is as rest relatively to the individual parts, II., 66. The laws of motion in planetary systems are the same as those of elementary particles, 274. Motion may be similar and dissimilar, or more and less harmonic, within the same medium, 295. See *Electricity*, *Heat*, *Light*.

NATURE. Nature performs her operations by means of the contiguity and connexion of things, I, 33. She consists as it were of infinite radii proceeding from a certain centre, connected by infinite circles and polygons, 33. Nature is a motive force which flows most freely into the spiral figure, 68. It is the power of bodies to act and to be acted upon in conjunction, 140. It is a force diversely modified, mechanically and geometrically, and is the same in the infinitely large as in the infinitely small, 207; II., 229, 230, 273. The uniformity of nature is particularly conspicuous in the elements, 219; II., 232, 291. Stupendous phenomena of nature are exhibited by the magnet and mariner's needle, II., 68. The state of nature is susceptible of variety, and the perfection and similarity of her greatest and least phenomena resemble in a finite degree the unity of the Infinite, 229, 230. One extreme of nature is above the senses of man, and the other below them, 230. Though nature multiply the heavens and mundane systems by myriads, yet in respect to the vast Infinite her whole empire is as nothing, 240. Nature, as to first principles and motive forces, is the same in all worlds; diversity consisting in the variety of the series, 246. Nature can give birth to her offspring only in the one place in which she abounds in first principles, 253. Nature is always in communion with causes, 301. She is no less beautiful in the ether by the play of her colors, than she is harmonious in the air by the modulations of her sounds, 310. Nature forms her last element where the senses begin, 336. In the smallest minutia we behold the principles of her mightiest operations, 341.

NATURAL POINT, the, is called the first ens when viewed *à priori*, or with respect to the Infinite; and the first simple when viewed *à posteriori*, or with respect to nature, I., 48, 51. It is produced by motion from the Infinite, 49, 54. It is a medium between the Infinite and the finite, 50, 53. It is the same as the mathematical point, or first ens of geometry, 51. It has only one limit, 51. It is the origin of every finite body, 52, 53. It consists of mere motion, 53, 55, 62; and consequently has neither parts nor extension, 59. Yet it is a most perfect figure, because not subject to modification, 60. No attribute can be assigned to this point except by analogy, 61. Its conatus flows into the gyres of the spiral figure, 64. It cannot be demonstrated by geometry, 65. Yet it contains the potency of all motion and production, 65; II., 242. It has no subsistence in the natural world except in the composition of the first finite, 79. Into the substance of which it enters, 96. See *Finite, first.*

NEEDLE, the magnetic, turns towards iron as a pole even at considerable distances, II., 64. Within the sphere, at any distance from the iron, the needle is turned towards the iron, not by an attractive force but by its own polar quality, 67. The polar direction of the needle is not caused by the conjunctive or attractive force of magnetism, but by its tendency to a constant parallelism with the magnetic element, 67, 148. See Experiments, 69—71. There are difficulties in taking observations regarding the inclination and dip of the needle, 95—107. Observations of the declination of the needle from various authors, made at different times and places, 108—143. The operation of the magnetic element is not immediately upon the needle or magnet, but upon the sphere by which it is surrounded, 148. The situation of the needle when left to itself is as the situation of the particles of the magnetic element, the determination of the latter therefore will give the position of the former, 148, 149. The method of calculating this position is a simple geometrical problem, 150—155.

PERFECTION, the, of a lower degree, consists in its similitude to that which is higher, I., 76. The more any entity is modified, the further it recedes from essential perfection, 99. Variety is the perfection of the world, II., 242, 243. It is more perfect and beautiful in proportion to its direct dependence on essential principles, 244.

PHILOSOPHY. The means more especially conducive to a true philosophy (that is to say, to a knowledge of the mechanism of the world) are three in number—EXPERIENCE, GEOMETRY, and the FACULTY OF REASONING, I., 2. By too great an accumulation of phenomena, and especially of those which are very remote from their cause, the mind is perpetually drawn aside from the end in view, and misled into a distant and contrary region, 6. No one is wise unless he has penetrated by means of a rational philosophy into the causes and principles of things, 14. Natural philosophy is capable of taking her station with nature herself, near the centre to which all natural things have reference, 33. True philosophy and contempt of the Deity are two opposites, 35. True philosophy detracts nothing from the credibility of miracles, 37. Man, in his state of integrity, was master of all philosophy or mundane science, 43.

PHOSPHORIC OR METEORIC LIGHT proceeds from the ether put into a state of local motion, or in an effort towards it, II., 297. The *ignis fatuus* is a local motion of the ether produced by the motion of certain small corpuscles, which may be put in motion either spontaneously, or by the tremulation of some hard body in which they are contained, and from which they proceed as effluvia, 297.

PLANETS. The planets derive their origin from causes, in time and place, II., 252. They are conceived in the solar vortex, near its active centre, 253, 264. They are produced by agglomeration of the parts on the disrupture of the solar belt, 262, 267. See *Chaos.* Bodies of three kinds are thus produced,—planets, satellites, and erratic bodies straying round the sun, generally called solar spots, 263. The planets are formed from the inner side of the solar belt, and inclose within themselves a part of the actives of the sun: the satellites are formed from the outer side, and inclose within themselves a volume of the vortical element, 266. The planets and satellites increase their distance from the sun until they arrive at their destined orbit, where they are in equilibrium with the volume of the vortex, 263—269. Every planet is but a vast finite, and is subject to the same laws as to motion, &c., as the smallest entity, 273, 274. Planets, by their local motion round the sun, are made actives, and also obey the same laws as minute bodies, 275.

POLES. From the spiral motion in the finite there arise two poles, one opposite to the other, I., 85, 170. From the motion of the finites in the first element, polar vortices are formed tending towards the centre, 155. The poles of all the elementary particles are in a parallel situation or line, 159. Their points of contact are most numerous about the poles, 163. The superficial matter or finites flowing through a surface, may, near the poles, pass into the surface of the neighbouring particle, 163. By this means a natural equation is preserved, 164. The vorticles, like their elementary particles, are conjoined with each other only at the poles, 220, 221. The poles of the magnet are formed by the magnetic sphere, 230. The spiral motion of particles in the vortex of our earth forms ecliptics and poles, II., 146. There are consequently two poles of the vortex as well as two poles of the earth, and the former are the same with the poles of the ecliptics, 146. The influx of the magnetic element is into the south pole of the earth, whence it tends in a spiral manner to the north pole, or cone of emergence, 146. The magnetic poles move round the poles of the earth from west to east, the northern performing its entire revolution in about 386 years: the southern in about 1,080 years. The whole period of the grand magnetic cycle being about 5,400 years, 147. See *Meridian*. The poles of the elementary molecules inclosed in the ethereal particles become more firmly colligated in proportion to the celerity of the motion, 283.

PRESSURE. There is a continual pressure of the particles of the magnetic element extending from one pole to the other, the action upon the particles being proportionate to the arcs or distances from the poles, II., 149. Every element exerts a pressure and acts proportionally to its altitude, 150. In the magnetic element the altitude is to be conceived as extending from one pole to the other, the particles being united polar-wise (see *Poles*), and only slightly connected equatorially, 150, 153. This element cannot press according to its altitude laterally, but only in the direction of its fluxion, 153.

RATIO. There must be a ratio between things which precede and those which follow, I., 52. There is no ratio however between the Infinite and the finite, 56. The first ratio of celerity among finites is in the first or simple finite, 81. Also the first ratio of dimensions, 81. The second ratio, in like manner, is in the second finite, 101. The ratio of celerity in the progression of the spiral from the centre to the periphery of its space, is simple, because it arises solely from the resistance of the points, 107. The duplicate ratio (see *Spiral*) is as the squares of the simple ratio, 108. There would be a constant geometrical ratio between the attractive forces and distances of two magnets were they perfectly similar, 248. Degrees, ratios, and figures vary according to contingents, II., 246. There is a ratio between the elasticity of the ethereal particles and the weight of the superincumbent volume, 289.

REASON. The rational principle consists in the ability to arrange into such order and connexion the reasons or proportional facts known from the world, as to exhibit their analogy and elicit further truth, I., 28. The third means by which we may arrive at a true philosophy in cosmology and at the knowledge of occult nature, is the faculty of reasoning, 29. The faculty of reasoning is acquired by cultivation, 31, 42. The faculty of the soul to reason and analyse extends its operations even to the senses, so that, by help of reasoning and analysis, or of the ratios of the things we sensate, we may arrive at some knowledge of those we do not, II., 230.

SATELLITES: see *Planets*.

SCRIPTURE. The Scriptures teach many truths concerning creation, I., 49. Whatever receives confirmation from Scripture must necessarily be true, 49.

SENSES. The senses can receive but grossly and in an imperfect measure the phenomena of the world, I., 1. There is a connexion between the organs of the senses and the soul, and the affections of the former can be in a moment transmitted to the latter, 10. The organs which mediate between the senses and the mind are fashioned by continual culture, 11. There is a connexion and harmony between the eye and the mind, and between the world and its elements and all the organs of sense, 24. Nature has designed that we should be instructed through the medium of the senses, II., 230. The ear, which is adapted to receive impressions from the air, is of a less delicate and subtile organization than the eye, which is adapted to perceive the modifications of the ether, 309. Our sensual organs are material, hence they perceive effects but not causes, 336.

SIMILITUDE, in, consists the sequence and connexion of all things in regard to existence and subsistence, I., 170. See *Figure.*

SIMPLE : see *Natural Point.*

SOLAR SPACE, the, primitively consisted solely of the actives of the first finite, I., 203. Surrounded by the finites themselves, 204. By means of motion among each other these first finites become second finites, 204. The surrounding finites may enter the interior space and become actives, 205. To the second finites succeed the first and second elementary particles, which form a large vortex round the sun, 205. See *Solar Vortex.* The active space is in the middle of the solar or stellar vortex, II., 233. Only one solar or active space can exist in one and the same vortex, 233. The fourth finites surround and set limits to the solar space, 258. In the vortex of finite elements immediately surrounding the solar space, the planets are conceived, 262—267.

STEAM : see *Aqueous Vapour.*

SOLAR VORTEX. In the formation of this vortex an active centre is the only force needed, I., 206. The vortical motion flows according to the equators and poles of the parts, and hence extends in a spiral figure and forms a zodiac, &c., 206. See *Element, magnetic.* The laws of magnetism are the same in the large solar vortex as in the smaller vortices of natural or artificial magnets, 232. It is also occupied by the magnetic element, II., 145. The motion of every such vortex is from the sun or star in its centre to the circumference, and differs in its procession towards the pole and towards the equator by reason of the geometrical difference in the figure of each part, 232 ; II., 345. See *Vortex.* The solar or stellar vortices are colligated according to the same laws which govern the vorticles of the magnet, II., 233. One vortex with its active space constitutes one mundane system. Several such vortices constitute one large sphere, as the whole sidereal heavens, in which every system inflects its course from one axis towards another, 233, 234. The axes of those vortices which are within the axis of the great sidereal sphere are disposed rectilinearly, and regard one and the same pole ; but those extending from the axis are variously inflected or incurvated according to their respective situations, 234, 235. When the axes of the mundane systems are not inflected, their gyrations are spirally circular, and their active centre in the middle. But when inflected, their gyrations are elliptical, and the active space is situated in one of the foci, 235—237. In this case the planets move elliptically, as those of our solar system which is not in the axis of the sidereal sphere, 235, 237. See *Sphere.* No change can occur in one vortex which is not in some measure perceived in the adjacent, as also in all the rest as far as the axis extends, and hence throughout the entire sphere, 237. The solar vortex, while the planets are yet only in conception, consists of a torrent of actives, passives, and elementaries, flowing in a chaos round the sun, 251, 252. The opinions of ancient philosophers suppose a vortex in which were comprehended all things which could conduce to the perfection of our system, 253—257, 269. The elements which form the solar vortex are perennially kept in their situation and motion by the constant action of the sun, 345. In the solar vortex there is a centripetal and centrifugal force, 346. From the general pressure of this vortex there arises a tendency to the centre of the earth, 348. The motion of the solar vortex is greatest at the centre, 349.

SPACE cannot be assigned to pure or total motion, I., 56. Its least dimensions being contained in the first finite which is the simplest figure, 75. There can be no motion without space, and no space without figure, 103 : nor without a boundary of passive finites, within which the actives are contained, 143. Space is the distance from one termination to another, 183. See *Figure.*

SPHERE. Unless the parts of a sphere are connected by a regular configuration and held together in orderly series and sequence, there can be no magnetic force, 283, 284. In this order are the effluvia surrounding the magnet, but not so the effluvia of iron, 283, 284. If such diverse spheres approximate, the former will reduce the latter into conformity with its own mechanical order, 284. The magnetic sphere is capable of flowing freely through all substances, however dense, 212, 213. This sphere only conjoins itself with iron or steel, or with such metals as partake of iron, 313, 314. The sphere of one magnet [loadstone] may be conjoined with the spheres of several pieces of iron, II., 1. Innumerable spheres may be formed within one and the same sphere, and each sphere may operate according to the situation and motion of its parts, 66. In the sphere of the magnet, as in the sidereal heavens, there are spiral gyrations and vortices, 231. The whole sidereal heaven is one large sphere constituted of innumerable solar systems or vortices, moving in harmonious order in accordance with their axes, 233, 234. The common axis of this immeasurable sphere is the galaxy [or milky way], where we behold the greatest congeries of stars : here lies the chain and magnetic course of the whole of our sidereal heaven, 237. There may be innumerable spheres or sidereal heavens in the finite universe; these may be colligated one with the other like the spheres of two magnets, and the whole visible sidereal heaven is perhaps but a point in respect to the universe, 238.

SPIRAL, (see *Motion,)* the, or perpetually circular, is the most perfect figure of motion, I., 64. The tendency of conatus is to the spiral figure, 66, and consequently the motion of the points amongst each other is spiral, 73. Similar is the motion of the first finite, which flows freely from the centre to the circumference, and from the circumference to the centre, 82. The motion of the spiral [in the first simple] is similar in every part of its space, 83. It is the only motion in which the points can be conceived to flow freely, 83. It possesses the highest mechanical potency, 83. Its flux and reflux could not take place without *loci*, through which any points flowing to the surface might afterwards return, 84. By the reciprocating motion and circulation of its parts two poles are produced, 85. By the divarication and enlargement of the poles into a cone-like figure, polar circles are produced, 86 ; and if the spiral figure prevail on the surface, greater and lesser circles answering to meridians, &c., 86, 173. The ultimate boundary to which the motion of the spiral arrives is a circle, 104. The spirals nearest the centre (both of the polar cones and surfaces), are the most highly spiral, and those nearest the circumference the least so, 104, 170, 215. The motion of the geometrical spiral terminates in its ultimate circle, 106. It decreases from its centre in a simple ratio, 107. Another ratio is given by the spiral at the points in which it crosses its radius; this duplicate ratio being as the squares of the simple ratios, 108. The spiral may thus be compared with the parabola, whose diameters are as the squares of its ordinates, 108. The ratio of the spiral being given, its lines may be ascertained by the differential calculus, 108. Within every spiral a small cavity is formed wider on one side than the other, 172. The spiral circles of a superficies are cut midway by the plane of the ecliptic, 172. The spiral motion results from the combination of the polar and equatorial motions, 215. The motion of the vortical spiral becomes more and more rectilinear according to its distance from the centre, and terminates in a right line, 215—217. There may be as many spiral gyrations in any volume as there are centres of motion, the spheres of which may interpenetrate each other, 218.

SUBSISTENCE. The world subsists by perpetual dependence upon its first principle or cause, II., 244. See *Connexion.*

SUN: see *Solar Space*, *Solar Vortex.* The Sun is the parent of its own vortex and consequently of the planets, II., 251, 252.

SUPERFICIES, the, of the elementary particle is constituted of the second finites, I., 143. The preservation of this surface and its figure depends on the equilibration of the internal and external forces, 144. It is most highly yielding and elastic, 146.

TELLURIAN VORTEX. The vortex of our earth, for a considerable part, consists of particles of the magnetic element, II., 145. The satellites and moons move within the vortices of the planets and earth, 145. The Tellurian vortex was formed round the earth, according with its magnitude and velocity, during its progression from the sun to its final orbit, 347. It occupies a place where it can be in equilibrium with the solar vortex, 348. The elements of the latter exercise a pressure within the Tellurian vortex according to their altitude, 348.

VORTEX. Any body falling into a vortex, in which the motion decreases from the centre to the circumference, if it be much heavier than the vortical element, will be carried along the radius to the periphery, I., 111, 345. But if lighter, will approach the centre, 111. If not too heavy, it will be carried along in the vortical current, and flow to the periphery through the spiral circles, 112; II., 345. If at any intermediate periphery it exactly balances the volume of the vortical element contained within such circumference, it will there stop, 112, and afterwards move in a circle at that distance round the centre of the vortex, 112. A vortical motion is produced when a volume of particles is circumfluent, accordantly with the parallelism or situation of each particle, 160, 161, 215, 231. The circles of vortical motion among the elementary particles which are further from the centre, more and more inflect themselves till they come into a right line with the axis, 162. The degrees of motion and pressure are according to the altitude or distance of the particles in a vortex, 166, 200. The particles of the first element flow most readily into the vortical motion, 175. The whole vortex is latent in its smallest part, which may be called a least vorticle, 102, 218. It is the necessary result of the combined forces of equatorial and polar motion, 215. Its motion terminates according to the situation of the parts, thus in a right line, 216. There may be as many spiral gyrations, or vorticles, in any given volume as there are centres of motion, and the vorticles may be conjoined conformably to their figure and motion, 218, 219. Were the figure and motion of adjacent vorticles not coincident, the motion of the one would obstruct or extinguish the motion of the other, 220. The conjunction of the vorticles with each other is similar to the conjunction of their parts, viz., according to the parallelism of their axes and the harmony of their motions, 220, 221. This consociation and cohesion of vorticles can only be overcome by force, 221. The potency of their cohesion is proportioned to the intensity of the motion, the curvature of the spires, and the coincidence of the planes, 221, 222. The cohesive force is greatest nearest the centre, less at intermediate distances, and totally ceases at the farthest distance, where the gyratory motion begins to be determined into a right line, 222. The axes of the magnetic vorticles are not in one parallelism and situation with the axis of the sphere but are incurvated according to its figure, 231. Were the axes in right lines, the motions in the vorticle would be concentric; were they incurvated, these motions would be excentric; and more or less excentric according to the degree of curvature and to the distance, 232. There is no ligation of vorticles or spires beyond an obliquity of 45°, II., 67. The elements are fluent in a vorticle, however minute, in the same manner as in a solar vortex, 232.

Water. A particle of water is perfectly similar to a particle of air, but highly compressed: it has no elasticity, and cannot be called an elementary; it is the first purely material finite, and is incapable of actuating itself like the preceding finites, II., 331. The origin of the aqueous particle is the same as that of the aërial, 332. See *Air*. The particles of water cannot move one amongst the other like elementaries unless there be interfluent elementaries to carry them, 332. The interfluen elementaries are ethereal particles, upon the expansion and rigidity of which the fluidity of water entirely depends, 333. In proportion as the interfluent ethereal particles are less active and rigid, the aqueous particles unite and concrete into a hard mass, 333, 334. When the ether is in its most mobile and rigid state, *i.e.* when the temperature is warmest, it renders the water most highly mobile, and makes it undulate and boil from the bottom to the top, 333. The particles of ether freely permeate the water and fill its interstices, but the aëreal particles, being of larger dimension, lie contiguous to the surface, 334. In every globule of water is contained all that had previously existed from the first simple, every genus of finites, actives, and elementaries, 341.

Wisdom. He who is possessed of scientific knowledges, and is merely skilled in experiment, has taken only the first step to wisdom, I., 13. The use of means to purify the mind from hereditary corruption that man may acquire true wisdom, must be indefatigable and constant, 42. The wisdom of finite man in relation to that which is Infinite is nothing, II., 232, 239, 247.

World. The first of the world and the first of geometry are the same, I., 51. The whole world is a pure system of mechanism, 51, and is incipient in the natural point, 54. This point, however, has no independent subsistence in the nascent world, 79. The active forces of the world resemble the motion and figure of the simple finite, 86, 91. The multiplication of finites and actives is the means of giving variety and beauty to the world, 191. The whole world is latent in every part, 202. No world can exist abounding in any variety of objects and phenomena without first passing through a succession of states and of intervals of time, II., 241, 242. The first principles or first cause of the world is its perpetual support, 244. No one world can be absolutely similar to another, 245.

APPENDIX.

In addition to the authors quoted in the Introduction, as having written upon magnetic phenomena, it has since occurred to us that it might prove interesting and instructive to the scientific reader, were we to contrast with the generalizing labours of Swedenborg and others upon this subject, the conclusions propounded by Ludwig Oken, who is still living and an earnest inquirer among the Germans, into the realms of the philosophy of nature. With this view we avail ourselves of the translation by a friend of the last edition (1843) of his "*Lehrbuch der Natuophilosphie,*" and transcribe in full what is there said concerning magnetism and its terrestrial manifestations. A disciple of that school of philosophy, which mainly took its rise with Schelling and numbers such names as those of Walther, Döllinger, Wilbrand, Steffens, Hegel, and others, no one, observes a critical historian (Burkard Eble) of his own times, has like Oken, " arranged with such genetic exactitude the multitudinous members of the universe, pourtrayed in so masterly a manner their mutual relations and resemblances, or shewn so clearly the bond of union that subsists between the most insignificant object and God; in a word, no one has traversed with the light of such genius the vast fabric of creation and placed it before us so vividly in one grand tableau." Oken's work is written in a numbered series of short and logically consecutive aphorisms, and the following translation has been extracted from the section upon Geology, which concludes the Ontological part of the German text.

MAGNETISM.

761. Two actions are necessarily manifested in iron, one cleaving or dividing, in so far as it is earth, and one indentifying, in so far as it is metal. Iron is the fluctuation between oxydation and reduction, between light and gravity, and this conflict of the two latter is *Magnetism.* Magnetism is the spiritual function of the metals.

762. Magnetism belongs essentially to the metals only. What is not metal, is metallic only according to idea or signification; it can be therefore aptly said, that such a body hath no magnetism, and that what has it, were metallic.

763. Magnetism is the direct property only of iron; it alone is the hybrid or heterogynous metal.

764. Magnetism appertains only to the other metals, in as far as they are positions of iron; and is the more powerful the nearer they stand in relation to iron.

All metals are magnetic in idea, whether magnetism be manifested in them or not.

765. All metals have originated through magnetism, through the radial polarity or the conflict of light and gravity. Magnetism is the action betwixt light and darkness, periphery and centre.

Magnetism, as being a metal generating action, tends toward the centre of darkness, of gravity. What in the earths and salts is the duplex tendency of crystallization,* is in the metals the identifying magnetism, as an everlasting operation of attraction.

---

* Allusion is here made to the mode of formation of a crystal, "which," (speaking of the function of the element, Earth, as *crystallization)*, Oken observes "cannot commence with the nucleus and then continue to grow, or actually *change,* into the perfected crystal, because it becomes only crystal in the conflict of linear and spherical action. As little as the sun can be produced without the planet, or vice versâ, so little can a nucleus subsist without what has been called the external shell or crust." "The nucleus is in fact determined by the shell of the crystal, namely by the polar axis. But inversely also the shell is determined by the nucleus, by the polar radii. A nucleus alone would be called a centre of a circle without circumference." The nucleus and its shell (or internal and external form of the crystal) are thus what our philosopher adverts to by the German words "duplexe Crystallisationstendenz."

766. Magnetism is still, however, not identical with gravity. Gravity is the centre abstractedly from the periphery; but magnetism is the centre only in relation to the periphery or light.

767. Polarity belongs to the essence, as well as the genesis, of magnetism; the metal subsists only through a constant resistance against the universal process of oxydation, against the developmental process of the earth-principles, which the metal is always striving to conceal. The metal is altogether the most mysterious essence of the planet. This resistance against the disclosure of the Innermost of the earth is magnetism.

Where magnetism has wholly attained this concealment, it renders the metal perfectly free and disappears, because it has become completely *incorporated.* In the noble metals it has attained what it is still seeking in iron.

768. Magnetism is a linear action with two different extremities, like the primary radius.* By one extremity magnetism runs towards the identical centre, by the other towards the partite, electrical periphery, towards the oxydized earths. One end will reduce, the other oxydize; one will become metal, the other earth. This is the distinction between north and south pole, the former centre, the latter periphery.

769. There is no peculiar magnetic fluid, any more than there is a matter of light, heat, and electricity. In magnetism the spirit only of the earth appears, as in light the spirit of heaven.

770. Magnetism is a constant process of excitation. This process of excitation is that which imparts and propagates. Magnetism has not been given, but excited. It breathes life only into the iron bar, whereby the latter awakes, and that is magnetism.

771. Every action, which induces differences in a line of iron, renders it therefore magnetic; thus electricity, unequal calefaction, and a blow whereby it is thrown into a state of vibration.

---

* For the reader fully to appreciate the sense of this passage it is necessary to bear in mind what Oken in his Pneumatogeny has said concerning the essence of the line, or radius as it is called in reference to the sphere. "The essence of the line consists not, in that its two extremities are prolonged into the infinite with equal significance; but in its *radiality*, *i.e.* that one end turned towards the centre has become central, convergent, absolute, but the other turned towards the periphery, divergent, finite, multiplicity. "The primary line is a line produced with two opposite characters. The central extremity is *o*, the peripheric is the partite zero or $o = \pm$ This radial line gives us the antetype of a new polarity. The two extremities are related not as + and — towards each other; but as *o* and + —."

An iron bar planted perpendicularly becomes magnetic, because it is then a radius of the earth. From the same cause it becomes magnetic, if placed in the magnetic meridian.

TERRESTRIAL MAGNETISM.

772. If all metals are in idea magnetic; so must the metallic veins, as products of magnetism, be magnetic lines. Every vein has a north and a south pole.

773. Since a vein is a magnetic line or magnetic needle upon a large scale; so must two veins abutting each other represent likewise a magnetic tension. A mountain of ores is a net of numerous magnets interlacing each other.

As one vein is related to another, so must one metalliferous mountain be related to the other; and thus two mountains of this character stand in magnetic polarity with each other. The whole earth is surrounded by a magnetic net.

774. As every metal, every vein, every mountain is in miniature a magnet, so must the earth be a magnet upon a large scale. There is a terrestrial magnetism.

775. Terrestrial magnetism belongs to the earth only in so far as the latter possesses a metallic quality; for magnetism is only the spirit of the metals, not of the other terrestrial substances, as the earths, inflammables, salts.

776. Magnetism is no general character of the earth, still less of the whole solar system, except in so far as the metallic substance lies at the basis of everything earthy. Magnetism does not operate outwardly over the earth.

777. The determinants of terrestrial magnetism are the *metallic veins,* or metallic beds in the crust of the earth.

778. Terrestrial magnetism has not been produced or determined by a magnetic nucleus; for a metal in the middle of the earth is a contradiction. All determinations of terrestrial magnetism depend upon the nature, character, distribution, number and direction of the metallic veins or beds.

779. Thus the direction of the earth's magnetic axis, its mutability, the declination of the magnetic meridian, the inclination or dip of the

needle, in short every phenomenon without distinction that concerns magnetism, must be derived from the nature of the metallic veins. Another momentum does not indeed exist for magnetism.

780. Terrestrial magnetism can be based only upon the polarity of the metallic veins, and this upon the ores they contain. It must therefore accommodate itself to the distribution of the chief masses of metals, especially of the idio-magnetic metal.

Now it has been ascertained that the noble metals are accumulated around the equator, such as gold, silver, copper, which may be regarded as non-magnetic.

In the northern temperate zones the mountains contain for the most part metals that are non-magnetic and semi-noble, as lead, zinc, antimony, which are usually combined as ores with sulphur. Iron, on the contrary, being the only magnetic metal, (a fact which is also determined chiefly by the magnetic needle in terrestrial magnetism) is accumulated in greater quantity towards the north pole, and becomes always rarer in occurrence towards the equator.

The southern hemisphere of the earth is indeed less known in this respect; but that towards the south pole iron reincreases in quantity, is rendered evident by the magnetic needle when conveyed beyond the equator inclining to the south pole. If the cause of the inclination upon the northern hemisphere be sought for in the presence of iron, the same must be done in regard to the southern. The arrangement of the metallic groups from north to south pole is thus; iron, lead, silver, lead, iron.

781. Iron has been deposited at both poles, and this in accordance with the genesis of metals, since iron is a half-reduced metal, and must consequently be subjected to the demi-action only of light. At or under the equator the Ferrogeneous is wholly reduced, and becomes noble.

782. At the south pole, however, there is obviously less iron than at the north pole, because there the greatest part of the planet is covered with water, and thus in general with less earth, whence it follows that less metal also is to be found.

From this alone it may be explained, why the magnetic needle beyond the equator still remains horizontal and first inclines about the tenth degree of southern latitude towards the south pole.

783. The north pole is thus stronger than the south pole. Consequently the two poles must be also inversely related to each other.

It is only from this antagonism of the two poles of the earth that we comprehend why upon the southern hemisphere the south pole of the needle dips towards the earth, and why the needle does not turn over. For if there were an equal quantity of iron upon both hemispheres, the southern must have the same magnetic pole, and thus attract also the north pole of the needle; and under the equator the needle must have actually no direction. The cause of the direction and dip of the needle rests in the antagonism of the two poles of the earth, and this again in the unequal masses of iron.

784. The action of terrestrial magnetism does not reside in the iron-formation alone, but in its antagonism to the reduced ores. The terrestrial magnetism is a tension between iron and silver. The lead imparts the poles.

785. As the earth is a globe, so are the two masses of iron situated nearer to its axis than the masses of silver and lead. If therefore the latter also exert any influence upon the direction of the magnetic needle, yet nevertheless the poles of magnetism must coincide nearly with the poles of the earth's axis, because the exciters of magnetism operate in this direction.

786. The magnetic meridian runs indeed in general from pole to pole; but as it is not the earth's axis itself which determines magnetism but the metallic masses, so the direction of the meridian deviates from the earth's axis in accordance with the distribution of these masses.

787. The magnetic needle can therefore assume a different direction on every spot of the earth, according as its relative position is varied between two principal masses of metals, and even as is indicated by the movement of the compass with the change of geographical longitudes, it is removed from one metallic mass, approaches another and by this becomes more powerfully attracted.

Upon the whole, however, the direction must tend toward the poles.

These are the phenomena of *declination* of the needle. We can now comprehend why this is present.

788. But there must be also spots upon the earth, where the needle points straight to the north, probably when it is between two metallic masses, or stands at a certain angle to them. These are the lines *without declination,* of which there are many as is well known, but which have not as yet been reduced to any law.

Nor can they ever be so, because we shall never become acquainted with the metallic beds.

789. As the solid land, so far as it projects out of the water, forms a horse-shoe figure, of which the two Americas represent one leg, Europe with Asia and Africa the other leg, the sea being interposed between them; so must the lines without declination fall principally in the ocean, between the earth's crura.

Moreover as these two crura of the earth are unequal in size, so must the one operate upon the needle more than the other, and in this respect also there can be therefore no regularity in the lines without declination.

Thus everything coöperates, to the effect of rendering the direction of the magnetic needle unequal; such as the distribution of metalliferous mountains, of masses of iron, of the earth's hemispheres, of the earth's crura, and inversely the earth has probably obtained this horse-shoe form through magnetism.

The cavities of the earth probably do not fall in there, because the ground, namely the mountains, are supported by metallic plates.

On this account the earth probably maintains an oblique position in her course.

According to this the earth's axis had first changed, when the metals were generated.

According to this also, the sea had rushed in first when the metallic veins were present.

Finally, in accordance with this the metals would be generated, when the whole earth was still covered, and the veins filled, with water. Unto such conclusions the philosophy of nature can alone conduct us.

The cause of a horse-shoe magnet operating more powerfully than any other shaped instrument resides probably in the form of the earth's crura.

790. The magnetic meridian varies, however, not only according to places, but to times also. This is explicable from the mutation of metals under the poles, as well as under the equator and in the temperate zones. Processes of oxydation and of reduction are always occurring, the more too, if the water recedes and tracts of land become dry. To this culture, the clearing of woods, the draining of swamps and probably mining operations themselves, conduce.

791. It must besides be clear to every one, who has learnt to look upon nature as a whole, that the numerous metallic masses upon the earth are not indifferent to the genesis of metal, that they are not strangers to iron; but that they stand invariably in one relation to it, which can only be magnetic; for therein only are they metals.

792. Magnetism is an infinity of tensions spread over the whole earth, of which the tension towards the axis is but the principal, not the sole tension. The expression hereof is the net of metallic veins.

793. Every magnetic line consists of an infinite number of shifting poles: for every magnetic line can be but the metatype of terrestrial magnetism.

ERRATA ET CORRIGENDA.

VOL. I.

Preface, p. xiv., bottom line, for "state tending to a spiral," read *state in spiral.*

Page 4, line 19, for "a priori," read *a posteriori.*

" 43, " 1, for "only disturb," read *not only disturb.*

" 84, " 2, for "mere reasons failing as they do," read *this kind of reasoning failing as it does*

" 107, " 6, for "circular circumference," read *circular periphery.*

" 108, " 14, for "line multiplied," read *line to that number or line multiplied.*

" 153, " 20 from bottom, for "out into," read *out among.*

" 154, " 14, for "compressed into a larger," read *expanded into a larger.*

VOL. II.

" 99, " 7 from bottom, for "the earth," read *also is the earth.*

" 102, " 14, for "designated in the maps," read *daily inserted in the tables* [log-book].

" 234, " 6, for "vorticles," read *vortices.*

" 262, " 3-4, dele "of the sun."

" 325, " 18-19, for "volume of first and second ethereal elementary particles," read *volume of ethereal, and of the first and second elementary particles.*

THE PRINCIPIA.

LONDON :
PRINTED BY WALTON AND MITCHELL,
Wardour-street, Oxford-street.

THE

PRINCIPIA;

OR,

THE FIRST PRINCIPLES OF NATURAL THINGS,

BEING

NEW ATTEMPTS

TOWARD A

PHILOSOPHICAL EXPLANATION OF THE ELEMENTARY WORLD.

BY

EMANUEL SWEDENBORG,

LATE MEMBER OF THE HOUSE OF NOBLES IN THE ROYAL DIET OF SWEDEN,
ASSESSOR OF THE ROYAL METALLIC COLLEGE OF SWEDEN,
FELLOW OF THE ROYAL ACADEMY OF SCIENCES OF UPSALA, AND OF THE ROYAL ACADEMY OF SCIENCES OF STOCKHOLM,
CORRESPONDING MEMBER OF THE IMPERIAL ACADEMY OF SCIENCES OF ST. PETERSBURG.

TRANSLATED FROM THE LATIN

BY

THE REV. AUGUSTUS CLISSOLD, M.A.

VOLUME I.

LONDON:

W. NEWBERY, 6, KING STREET, HOLBORN;
H. BAILLIÈRE, 219, REGENT STREET;
OTIS CLAPP, SCHOOL STREET, BOSTON, UNITED STATES.

1846.

TO

THE SWEDENBORG ASSOCIATION,

INSTITUTED

FOR THE PURPOSE OF PROMOTING THE DIFFUSION OF ALL LITERATURE

WHICH MAY TEND TO

THE CHRISTIANIZATION OF SCIENCE,

AND HENCE FOR THE PURPOSE OF PRINTING AND PUBLISHING THE

PHILOSOPHICAL AND SCIENTIFIC WORKS OF

EMANUEL SWEDENBORG,

THIS HUMBLE ATTEMPT AT A TRANSLATION OF

THE PRINCIPIA,

IS MOST RESPECTFULLY INSCRIBED BY

THE TRANSLATOR.

CONTENTS OF VOLUME I.

PART I.

PAGE

Introduction by the Translator i

Dedication lxxxix

Preface xciii

Chap. I. On the means which conduce to true Philosophy, and on the true Philosopher 1

II. A philosophical argument concerning the First Simple from which the world, with its natural things, originated; that is, concerning the First Natural Point, and its existence from the Infinite. . . . 46

III. A philosophical argument on the First or Simple Finite, and its origin from Points 72

IV. A philosophical enquiry concerning the Second Finite, and the manner in which it derives its origin successively from the Simple Finite. Also, general observations on its coexistent; which we have denominated the Active of the First Finite; and on the manner in which it is geometrically derived from the First and Simple Finite. 96

V. Observations specifically on the Active of the First Finite: on its origin from the First Simple Finite; on its motion, figure, state, and other attributes and modifications: shewing that this Active is one, and constitutes the sun of our system: that, in like manner, it forms the first elementary particles 120

VI. On the First and most Universal Element of the Mundane System, or the First Elementary Particle compounded of Finites and Actives; of its motion, figure, attributes, and modes; of its origin and composition from the Second Finite and the Active of the First Finite; of its constituting the solar and stellar vortices 140

VII. On the Actives of the Second and Third Finite 177

PAGE

VIII. On the Third Finite or Substantial 190

IX. On the Second or Magnetic Element of the World; that is, of the next Elementary Particle composed of Third Finites and of the Actives of the Second and First Finite. Of its motion, figure, attributes, and modes. That this Element, together with the former, constitutes the solar vortex, and is the one which principally contributes to the phenomena of the magnet 195

X. On the existence of the Sun and the formation of the Solar Vortex. 203

PART II.

Chap. I. On the Causes and Mechanism of the Magnetic Forces 211

II. On the Attractive Forces of two or more Magnets, and the ratio of the Forces to the Distances........................... 244

III. On the Attractive Forces of two Magnets when their Poles are alternated 261

IV. On the Attractive Forces of two Magnets when their Axes are parallel, or when the Equinoctial of the one lies upon the Equinoctial of the other 265

V. On the Disjunctive and Repulsive Forces of two or more Magnets when the Cognominal or Inimical Poles are applied to each other 270

VI. On the Attractive Forces of the Magnet and of Iron 283

VII. On the influence of the Magnet upon Ignited Iron 308

VIII. On the quantity of Exhalations from the Magnet, and their Penetration through Hard Bodies, &c. 312

IX. On the various modes of Destroying the Power of the Magnet; and on the Chemical Experiments made with it 332

X. On the Friction of the Magnet against Iron, and on the force communicated from the former to the latter.................. 362

INTRODUCTION BY THE TRANSLATOR.

The two volumes *octavo* now presented to the reader are a translation from the original Latin of the first of three volumes *folio,* published by Swedenborg at Dresden and Leipsic, in the year 1734, under the general title of *Opera Philosophica,* &c. The first of the three is entitled specifically The Principia, &c., and is a treatise upon the First Principles of Natural Things: it forms in itself an independent work, being appropriated to certain philosophical and scientific subjects, while the two latter volumes are confined to such as are commonly called practical.

Of the contents of The Principia, Swedenborg has presented a general view in the Preface written by himself, which will be found in the sequel; it is likewise again presented by himself in another form at the close of the Third Part of the Principia, in the *Appendix.*

With regard to the contents of the Second and Third volumes *folio,* the reader is referred to the translations of Swedenborg's two Prefaces, which have been added at the end of our second volume, a perusal of which will furnish a general view of the entire contents of the *Opera Philosophica.*

The object of the *Principia* is to trace out a true *system of the world,* and in so doing the author has distributed his subject into Three Parts. The First Part treats of the origin and laws of motion, and is mostly devoted to the consideration of its first principles; which are investigated philosophically, then geometrically, their existence being traced from a first natural point down to the formation of a solar vortex, and afterwards from the solar vortex to the successive constitution of the elements and of the three kingdoms of nature. From the first element to the last compound it is the author's object to shew that effort or conatus to motion tends to a spiral figure; and that there is an actual motion of particles constituting a solar chaos, which is spiral and consequently vortical.

In the Second Part the author applies this theory of vortical motion, to the phenomena of Magnetism, by which on the one hand he endeavours to test the truth of his principles, and on the other by application of the principles to explain the phenomena of Magnetism; the motion of the magnetical effluvia being as in the former case considered to be vortical.

In the Third Part the author applies the same principles of motion to Cosmogony including the origination of the planetary bodies from the sun, and their vortical revolutions until they arrived at their present orbit; likewise to the constitution and laws of the different elements, the motions of all which are alleged to be vortical; likewise to the constitution and laws of the three kingdoms of nature, the animal, vegetable, and mineral; so that the entire Principia aims to establish a true theory of vortices, founded upon a true system of corpuscular philosophy.

Although Swedenborg has thus entered into subjects, which from time to time have engaged the attention of the most distinguished authors, yet in the course of his Work he has mentioned the name of scarcely any; the reason for which he has thus assigned in the *Appendix*, Vol. II., p. 365.

"To me it is a matter of indifference whether I win the favourable opinion of every one or of no one, whether I gain much or no commendation; such things are no objects of regard to any one whose mind is bent only on truth and a true system of philosophy; should it therefore happen that I should gain the assent or approbation of others, I shall receive it no otherwise than as a confirmation of my having pursued the truth. I have no wish to persuade others to lay aside the principles of the various illustrious and talented authors who have adorned the world, and in place of their principles to adopt my own: for this reason it is that I have not made mention so much as of one of them, or even hinted at his name, lest I should injure his feelings, or seem to impugn his sentiments, or derogate from the praise which others bestow upon him. If the principles I have advanced have more of truth in them than those which are advocated by others; if they are truly philosophical and accordant with the phenomena of nature, the assent of the public will follow in due time of its own accord; and in this case, should I not gain the assent of those whose minds, being prepossessed by other principles, can no longer exercise an impartial judgment, still I should gain the assent of such as are able to distinguish what is true from what is untrue, if not in the present, at least in some future age."

About the time the author was born, Sir Isaac Newton published his *Mathematical Principles of Natural Philosophy*, and as the very existence of vortices was by most persons supposed to be disproved by that work, it is not improbable that in the reasons above assigned Swedenborg had in view this controversy, which had been carried on by some with considerable vehemence.

As then, for these reasons, the author has in the course of his Work omitted the mention of other writers who have treated of the same subject, it seemed incumbent upon the translator to endeavour in some measure to supply this omission, in order to shew the place of the present Work in the history of philosophy and science, and its relation to both, not only in the age in which Swedenborg lived, but also in the present day.

The principal authors who have advocated the theory of vortices previously to Swedenborg are Kepler, Descartes, and Leibnitz.

We propose in the first place to give an outline of their respective views, to which we shall subjoin the theory of Swedenborg; which is the more desirable, as there appear to be symptoms in the present day of a *return to a theory of vortices of some kind or other*, and consequently it may be interesting to keep in view the different theories which have been advanced upon the subject; we shall next offer some remarks on Swedenborg's theory of Magnetism; and lastly, on the Nebular Hypothesis and other topics connected with it.

First, then, with regard to the vortical theories of Kepler, Descartes, and Leibnitz, we shall derive our account principally from the *Elements of Astronomy, Physical and Geometrical, by*

David Gregory, M.D., Savilian Professor of Astronomy at Oxford, and Fellow of the Royal Society, A.D. 1701.

In the tenth section of this work the author treats of the causes and reason of the motions of the planets assigned by philosophers, and in prop. 66, explains briefly the substance of the celestial physics of Kepler. To transcribe the whole would be to occupy a greater space than could be allowed in this Introduction, we can therefore only present a brief outline of the subject.

According then to Dr. Gregory, Kepler, who wrote in the year 1595, maintained that the sun is a magnet revolving on its own axis, the position of which was given by the immediate agency of the Divine Being. The solar substance or magnet he regarded as immaterial and as a centre from which emanated in right lines or radii, the same species of substance; and since the sun revolved on its axis, the same species of substance emanating in radii revolved with it and thus constituted a vortex. Moreover the whole surface of the sun was considered as attractive, the centre of the sun as repulsive; the powers of attraction and repulsion were considered to be equal, and consequently when acting upon a planet as maintaining it at any given distance in its situation. But inasmuch as a planet thus acted upon by a vortex, would describe a circle and not an ellipse, therefore in order to account for the eccentricity of the orbits, he supposed that each planet also was a magnet, one side of which was attractive the other repulsive. As the planet turned its attractive side toward the sun, it gradually arrived at its perihelion; as it turned its repulsive side toward the sun, it gradually arrived at its aphelion. But although Kepler thus accounted for the eccentricity of the planetary orbit, he had not as yet accounted for the inclination of its plane to the plane of the equator. Therefore he conceived that the power by which the planet was urged out of the plane of the equator was similar to that by which a boat is urged out of its course, by holding on one side of it an oar in the water, or by which the course of a ship is diverted by turning the helm. Hence he assumed in the planet certain imaginary lines or fibres parallel to each other and to the plane of the ecliptic. These were supposed to correspond to the rudder or the oar, and meeting the stream issuing from the sun at a given angle of inclination to urge the planet above or below the plane of the equator, as required. For the mechanism by which the eccentricity of the planetary orbit was more particularly accounted for by means of imaginary *libratory fibres;* as also by which the inclination of the plane of the planetary orbit to the plane of the equator, was affected by means of imaginary *fibres of latitude,* the reader is referred to the work from which the present account is taken.

In refutation of the foregoing hypothesis, Dr. Gregory observes, first, that supposing the planet to exert no attractive or repulsive power, as Kepler presumed in the case of Venus, it would not be carried in a circle round the sun, but would have a tendency to a right line; hence that if the planet is supposed to describe a circle, some other force tending to the centre must be presumed beside the attractive power of the planet which is turned to the sun only for a certain time. Secondly, Dr. Gregory observes, that according to Kepler's hypothesis, when the planet is ascending from its perihelion to its aphelion, and consequently has its repulsive side turned toward the sun, instead of describing a curve concave to the sun, the curve would be convex. Wherefore a planet whose orbit is an ellipse, having the sun for a focus, must necessarily be urged, even in its ascent from the sun, from the perihelium to the aphelium, by a force tending to the sun; since an ellipse is concave toward both foci. Thirdly, Dr. Gregory observes, p. 147, that Kepler,

"In his enquiry into the proportion of the planetary orbits, he assumes some things plainly contrary to observation, how much soever it is that they agree with his imagined architypical ratios: as that the magnitudes of the planetary bodies are as their distances from the sun; and that their densities are reciprocally as the square roots of their magnitudes. From whence it follows, that the quantity of matter in the planets is directly as the square root of their distances from the sun: because the quantity of matter is as the magnitude and density conjunctly. But every body knows that Mars is less in bulk than Venus, which notwithstanding ought to be as big again as Venus, according to *Kepler's* reasoning; because distant as far again from the sun. Observation informs us, that the globe of Jupiter is bigger than Saturn, though it ought by the aforesaid rule to be as little again."

Moreover Dr. Gregory observes, p. 148, that,

"Kepler's system, about the manner of the sun's carrying round, attracting, or repelling the planets, is founded upon what is contrary to one of the chief laws of nature and motion, whereby care is taken that there be a reaction always contrary and equal to any action. For according to Kepler, in Epit. Book IV., *This virtue of expulsion and attraction is not in the planets themselves, but in the sun only. And though the attractory and repulsory power of the sun be extended to, and affect the planets, yet the like power of a planet does not reach to the sun and affect it.* For were it so, he confesses, that *the sun would be moved out of the place it has in the centre of the world, by the planets, in the reciprocal ratio of their bodies; or at least it ought to titubate or reel as it were, being sometimes attracted more this way, sometimes more that way, according as more planets happen to come together on the same side of the sun, having similar powers.* But this he entirely gets rid of, by denying a mutual attraction."

We have thus presented a brief outline of Kepler's theory of vortices, and also of the objections which have been urged against it. We proceed in the next place to the theory of Des Cartes who wrote his treatise in the year 1643; and in so doing we shall first state the theory and then the objections.

Dr. Gregory observes, p. 152,

"Cartes supposes then, that all the matter of which the visible world is made, was, in the beginning of things, divided by God into particles very nearly equal, of a moderate size, and equally moved, not only each about its proper centre, and separately from one another, so as to compose a fluid; but several also about some other points, in like manner remote from one another, and so they composed various vortices. Afterwards he resolves these equal particles, worn a little by their intestine motion, into globules of different sizes, all which he calls particles of the second element; and a part of a fluid formed out of the irregular minute parts rubbed off from the corners of the globules, and moved always with a very great rapidity, he calls the matter of the first element. Now, there being more of this sort of matter than was necessary to fill up the interstices of the globules, what remained was thrust down towards the centre by these globules receding from their center, by reason of their circular motion, and being there collected into a spherical body, constitutes the body of the sun in the centre of each vortex. Besides this equal motion impressed originally upon these particles, about the centre of the vortex, the sun, just formed in the centre of the vortex, and revolving about its own axis the same way with the rest of the matter of the vortex, and always emitting some of itself along the narrow passages that are within the globules of the second element towards the ecliptic, or circle, lying just in the middle between the poles, (receiving as much at its poles from the neighbouring vortices, as it emits,) has a power of carrying those globules along with it; those nearer, quicker, but those farther off, slower. But since these lower globules of celestial matter move quicker than the superior ones, they ought also to be less. For if they were greater or equal, they would upon that account have more forces, and therefore would become uppermost by their centrifugal force. And all these particulars will be the same in any vortex whatever, within certain limits, beyond which the upper globules are moved quicker than the lower, being as to their sizes equal. These limits in the solar vortex he places about the orb of Saturn, or a little beyond.

"These things being supposed, if any star, which being placed in the center of its vortex, does the office of a sun, should happen to be covered with spots, and by that means weakened so as to be overcome and carried along by the neighbouring vortex of the sun; if this star be but capable of a less degree of agitation, or have less solidity than the globules of the second element that are near the circumference of our vortex, yet something more than some of those which are nearer the sun; we are to understand that this star, so soon as it is arrived into the vortex of the sun, ought to descend continually towards its center, till it arrive at such celestial globules as it is equal to in solidity or aptitude to persevere in its motion along right lines. And when it has at last got thither, it will neither approach nearer to the sun, nor yet farther off from it, unless it be something propelled from thence, by some other causes afterwards to be related: but being in *equilibrio* with those celestial globules, will revolve about the sun with them, and become a planet. Every one of them therefore is at rest, in that part of the heaven where it is; and all the variation of situation observed in them, only arise from the motion of the matter of heavens or vortex that contains them. According to this system then, nothing hinders us from imagining the space, in which at present the single vortex of the sun is contained, to be at first divided into seventeen or more vortices; and that they were so disposed, that the stars, which they had in their centres, were by little and little at length covered with several spots, and then these destroyed by other vortices, the one quicker, the other slower, according to their different situation. So that since these four, in whose centres were the Sun, the Earth, Jupiter, and Saturn, were bigger than the rest, the stars which were in the centers of the five lesser that stood about Saturn, descended towards Saturn; and those in the centers of four others about Jupiter, towards Jupiter; in like manner the moon near the earth, towards the earth;

afterwards Mercury, Venus, the Earth, with the Moon, and Mars, (each of which stars also formerly, had a vortex,) towards the sun; and at length Jupiter and Saturn, together with the lesser stars about them, sunk together towards the sun, much greater than themselves, after their own vortices were destroyed: but the stars of the other vortices, if they were ever more than seventeen in this space, passed away into comets, moving almost in a right line out of one vortex into another, and never returning. So that now, since we see the primary planets carried at different distances from the sun, we are to judge, that this happened, because the solidity of such of them as are nearer the sun, is less than that of those that are farther off: and that from hence it came to pass, that the same part of the moon is turned towards the earth, or at least does not defect much from it, because its other part, which is turned from the earth, is something more solid, therefore in moving round the earth ought to describe a great compass. And since we see the inferior of those higher planets to move round quicker, we still judge it to arise from hence, that the matter of the first element, which composes the sun, by whirling round very rapidly, carries along with it the nearer parts of the heaven, and the planets swimming in them, which are there relatively at rest, better than the more remote. Jupiter, the Earth, &c., revolve about their own axes, because they were formerly lucid stars placed in the centers of some vortices, and no doubt gyrating there like our sun, and even now the matter of the first element collated in the centers of them, still retains the same motion, and impels them.

"Lastly, we are not to think that all the centers of the planets are always accurately in the same plane, nor the circles they describe perfect and complete: but, as we see it happens in all other natural things, only nearly so, and in time perpetually changing. For since all the bodies that are in the universe, are contiguous, and act upon one another, the motion of each depends upon the motion of all the rest, and is therefore varied innumerable ways. On which account we find, that though all the planets affect a circular motion, yet none of them ever describe circular ones, but always err something from them, both in longitude and latitude."

Such is the theory of vortices maintained by Des Cartes, according to Dr. Gregory, who then proceeds to point out and refute its errors. After observing that the intermingling of the vortices must produce confusion, which is his first objection, he thus continues, p. 164,

"Further because the parts of the vortex, generated in the manner above-described, that are nearer the center, being* moved quicker, urge the exterior, and constantly communicate motion to them by that action; and these exterior particles transfer at the same time the same quantity of motion into others that are still more exterior; because (by hypothesis) it is a condition of the vortex, that each part of the fluid persevere in its motion uniformly, and is not incited, sometimes more, sometimes less, in the same distance from the center: it is evident that motion is perpetually transferred from the center to the circumference of the vortex, and absorbed by the infinity of the circumference. And therefore to the conservation of a vortex in the same state, there is required some active principle, from which the central sphere (or sun of that vortex) may always receive the same quantity of motion, as it impresses on the matter of the vortex. But from whence the Cartesians can get such an active principle residing in each sun that moves the whole vortex, I cannot see; since Cartes himself, in parag. 146, third part Princ. Phil., boldly says, 'There is nothing to be met with in the phenomena of the planets, that cannot be accounted for from what has been already said.' The penetrating Kepler saw well enough the necessity of such an active principle in the central spheres of the vortices: *and therefore lest the motion should languish by degrees,* which Creating Omnipotence impressed upon them in the beginning of things, he would have it *maintained either by the perpetual care of the Creator, or by the assistance of a spirit destined to that employment.*

"For without such an active principle, the central spheres and the interior parts of the vortices, always propagating their motion into the exterior, and receiving no new motion, must necessarily move slower by degrees, and cease to move circularly. And consequently this world of Des Cartes, without such an active immechanical principle naturally tends towards rest and its dissolution.

"Des Cartes and the Cartesians acknowledge, that the bodies which are carried in this vortex and return again, are of the same density with the parts of the vortex, where they are placed, and move by the same law with them, as to the velocity and determination of the course; the deferent fluid, and that body which is carried by it, differ only in this, that the parts of the bodies thus carried by the vortex, keep the same situation in regard of one another; and that they are as it were congealed and solid parts of the vortex, and cannot be mingled together by an intestine motion, as the fluid parts of it are; being, in other respects, entirely equal. Since therefore the parts of the vortex† revolve by this law, that their periodic times are in the duplicate ratio of their distances from the centre, the planets also carried about the sun, and at relative rest in the fluid matter of the vortex, in which they swim, will revolve by the same law. Since therefore the Earth, for instance, completes its period in a year, the period of Saturn, whose distance is 9½ times the distance of the earth, would be 90 years, when it is not quite 30 years: after the like manner the period of Saturn would be 27 years, whereas it is not 12: and all the superior planets would have periods greater than the truth; and the inferior less. If the patrons of vortices answer, that the vortices are not uniformly fluid,* but the parts constituting them in the recess from the center are grosser, as Cartes says in parag. 82, part 3; then† the more remote planets from the sun are still slower, whereas they are two slow already, (according to this system;) and it is evident from this constitution of the vortices, according to Cartes, there will be a greater distance from observation, than if the vortices were made up of an uniform fluid. Since therefore it has been demonstrated, that the parts of the vortex revolve by a very different law from that which is observed in the planets; namely, that the periodic times of the parts of the vortex are as the squares of the distance from the center, if the matter of the vortex be homogeneal; or as some higher power of the distances, if the matter of the vortices be grosser at a greater distance; whereas in the meanwhile‡ in the planets, the squares of the periodic times are as the cubes of the distances; (that is, the periodic times of the planets are as those powers of the distances, whose exponents are $\frac{3}{2}$, which are much lower than those whose exponents are 2, or a number greater than 2;) it is evident therefore, that the planets are not carried by any such corporeal vortices.

---

* Preceding prop. † Same prop.

"If the vortex were extended *in infinitum,* it is evident§ that each part of the fluid ought to describe a perfect circle, and‖ that the aberration from a circular path proceeded from the rigid vessel (or what is equivalent to it), in which the matter of the vortex is contained. From whence it evidently follows, that the greater the vortex is in respect of the path described by its fluid part, (or by the planet carried together with it,) the more ought the path of the planet to come up to a perfect circle; that is, the eccentricity of a planet nearer to the sun will be less than that of one more distant from the sun; whereas astronomical observations testify and assure us, that the orbit of Mercury is much more eccentric than that of Saturn. Again, because¶ the particles of the vortex, and the planets carried along with them, will be moved in lines almost conformed to the figure of the vessel, in which the fluid is contained, the aphelia of all the planets viewed from the sun will be posited towards the same fixed stars; whereas the aphelia of the planets are at a great distance from one another, as Jupiter's and the Earth's, by a quarter of a circle; Mars's and the Earth's, by a third part of a circle; those of Mars and Venus are almost opposite. Besides, the matter of the vortex (like a river) being within narrower bounds, (by the laws of mechanics) ought to move quicker than when it moves freely in a broader channel; and that in the reciprocal ratio of the breadths of the channels, or what is equivalent to them" . . . &c.

---

* As was supposed in the preceding prop.

† By Corol. 1. preceding prop.

‡ By prop. 22.

§ From preceding prop.

‖ By Corol. 2.

¶ By Corol. 2, preceding prop.

Whereas it may be proved that this is not the case.* Again p. 168,

"A body carried by a vortex, and of the same density with the parts of the vortex in which it is, in its return round, if it be not otherwise hindered, describes a circle; to whose plane the axis of the central sphere, whereby the fluid is turned about in the form of a vortex, is perpendicular: and if the path of the body be inclined to this plane, that inclination will be continually lessened, and they at last will coincide. For it is evident† that each part of the fluid composing the vortex, describes such a circle; wherefore even the planet, which is carried only by these particles being relatively at rest between them, will also describe such an one; and if by any external force impressed it deflect a little from hence, the inclination will be lessened by degrees by the encounter of the particles of the fluid describing the above-mentioned circles, and the planet itself will describe such a circle, being thus at last relatively at rest in the fluid of the vortex, and carried about together with it. But there is not one planet to be found having the axis of the sun perpendicular to the plane of the orbit; nor during these two thousand years, wherein observations have been made, has the inclination of the orbit of any planet to that plane been found lessened; nor are there any fibres of latitude assigned by these philosophers in the planets, for the preserving the same inclination. But the apology that Cartes brings for the various eccentricity of the planets, and the various inclination of the orbits to one another, and the various situation of the aphelia, which is, in parag. 34, part 3, Princip., (namely this: *But as we see it happens in all other natural things, that they are only nearly so, and in succeeding ages are continually changed,)* shews plainly that he was unacquainted with the calculatory part of astronomy. For though it cannot be denied that physical causes have a place in the motion of the stars, yet no person used to these matters will judge that such casual and almost irregular inequalities, (such as Cartes seems to insinuate,) are to be admitted in the motions of the stars; but will rather say, with that most acute and best fitted for astronomical speculations, Jer. Horrox, who laboured to defend the contrary opinion, *We may justly wonder at some slingers or engineers, that can throw bodies out of slings or cannons with such incredible certainty of aim. But if we see so great exactness in those momentaneous things, that are moved through the thick unsettled air; shall we not expect a much greater in those perpetual bodies which are revolved in a quiet and pure ether by an eternal law?*

---

* As the demonstration requires a figure for illustration, it is omitted. The reader is therefore referred to Dr. Gregory's Work.

† From the demonstration of the preceding prop.

"Since the globules composing the fluid of the solar vortex are lesser near the sun, and consequently their mass, contained in a given space and filling it, is less dense than in a greater distance from the sun; it follows, that even the planets which are of the same density with the particles of the vortex, in which they swim, are less solid the nearer they are to the sun; which Cartes also acknowledges in parag. 147, part 3, of Princip. But the contrary to this we shall demonstrate in its proper place hereafter; namely that each planet, the nearer it is to the sun, the solider or more dense it is; that is, it contains more matter under an equal bulk. Which also agrees much better with the architypical ratios, geometrical concinnities, and final causes: from the consideration of which, it is evident, that the Divine Being has placed the planets at different distances from the sun, so that each, according to its degree of density, may enjoy a greater or less degree of heat; and consequently the more dense planet is nearer the sun, since all more dense sort of matter require a greater heat for the performance of natural operations. And though the ratio of the density of the planet be not the same with what Kepler makes it, namely the reciprocal of the roots of the distances from the sun; but the reciprocal of the distances from the sun drawn into the roots of the apparent distances: yet here (where he was most of all mistaken) Kepler came at this general proposition, by his archetypical ratios, that the denser planets are nearer the sun; whereas Cartes, who was since him, from a neglect, (or rather contempt) of the archetypical ratios and final causes, cherished opinions entirely contrary to these final causes, and true physics or mechanics, (which generally lead us to the same thing;) and amongst others, this opinion, that the solidity of the planets near the sun, is less than that of those farther off.

"Tycho formerly, from the motion of the comets, demonstrated, that the planets were not moved in solid orbs; because the comets passed through them. The same comets do now with equal evidence shew, that the planets are not carried by corporeal vortices; seeing the comets move in paths very oblique, and sometimes cutting the plane of the zodiac at right angles, and sometimes directly contrary to the course of the planets, and they preserve these motions with the greatest freedom and length of time, being subject to this universal law, that by a radius drawn to the sun, they describe areas proportional to the times; which would be altogether impossible, if the entire matter of the vortex were carried about the sun with a force sufficient to carry along with them the vast bodies of the planets. Nor does it help Cartes at all, that he has banished the comets beyond Saturn, contrary to the credit of all observations, (which Tycho and the astronomers never forced to serve their hypotheses, as Cartes would insinuate;) since the matter of the solar vortex beyond Saturn (according to himself) has a greater moment to carry them along with it, than near Venus and Mercury; both because the globules composing the vortex are greater there than here; and especially because they are moved much swifter, since they run a circle immensely greater *within a few weeks*, as Cartes has it, parag. 62, part 3, Prin. From all together, and each of these in particular, it is evident, that this hypotheses of vortices is entirely disagreeable with the phenomena of astronomy, and conduces not so much to the explainings as the disordering of the celestial motions."

Such is Dr. Gregory's refutation of the vortical theory of Des Cartes. We therefore in the next place proceed to that of Leibnitz; in the exposition of which, Dr. Gregory observes, p. 172,

"It is so natural in enquiring after the causes of the celestial motions, to seek them in the ambient fluid ether, that the philosophers have looked upon the planets to be carried about the sun, after the same manner as so many straws swimming in water, are carried about by the water put into the motion of a vortex, by a stick whirled about its axis in the middle of a vessel at rest. This ancient opinion lay neglected for a long time: but in the last age was revived by some great men; for before Cartes, it was approved of by Torricellius and Gallileo; for the reasons without doubt, summarily proposed about the beginning of prop. 71.

This opinion pleased so well, that that most acute philosopher, Mr. Leibnitz, (even after the publication of *Newton's Mathemat. Princip. of Nat. Philos.)* adopts it; and *judges that there remains now no more than to shew how the causes of the celestial motions arise from the motions of the ether, or (speaking astronomically) from deferent orbs,* *but then such as are not solid, but fluid.* A name so celebrated among geometricians certainly deserves to have his *essay upon the causes of the celestial motions* (which he communicated to the learned world in the *Acts of the Learned,* published at Leipsic, in February, 1689) exactly considered.

"For Mr. Leibnitz (if any man) is able to accommodate vortices to the celestial motions, and *assign reasons for the laws of the heavenly bodies discovered by Kepler.* Especially since *he has attained some peculiar light in that matter, and the enquiry he made, seemed* to himself, who is so penetrating a person, *to succeed very well and agreeable to nature, so that hereupon he had good hopes of having arrived at the true causes of these motions.* We will therefore lay down the method this philosopher uses in explaining these great works of nature, in as few words as possible, and, as near as we can, in his own.

"First, Leibnitz takes for granted, that all bodies which in a fluid describe a curve line, (and consequently that the planets themselves,) are acted upon by the motion of the fluid itself. For all bodies describing a curve, endeavour to recede from it along a right line, which is a tangent, (from the nature of motion;) there must therefore be something that keeps them in. But there is nothing contiguous except the fluid, (by supposition,) and no endeavour to move thus can be restrained but by a contiguous body likewise in motion, (from the nature of matter;) the fluid itself therefore must necessarily be in motion.

"Since from the most exact observations that have been made, every planet describes an orbit about the sun, according to this law, that by radii drawn from the sun to the planet, areas are always cut off proportional to the times; it is reasonable enough that the ether or fluid orb of each planet should move about the sun after such a manner as may agree with the said law of motion. And this will be done, if each of the innumerable circular concentric orbs of smallest thickness, into which the fluid orb of the planet is divided by the mind, have its proper circulation, so much the swifter in proportion as each of them is nearer to the sun; that is, if the velocities of circulating, in the parts of the fluid, are reciprocally proportional to the radii or distances from the sun. By which means it will happen, that whether the planet be more or less distant from the sun, the sectors that are described in equal times by the radius, are equal. For the said sectors are in a ratio compounded of the direct ratio of the radii or distances from the sun, and of the reciprocal of the arcs or circulations, and therefore (from the nature of the circulation) in the ratio of equality. The circulation above described (where the velocities of circulating are reciprocally proportional to the distances from the center) he calls *harmonic,* because supposing the distances from the center to increase equably or arithmetically, the circulations decrease in an harmonic progression; being reciprocally proportional to the quantities that are in an arithmetic progression, which is the known property of harmonic proportionals.

"This great man therefore supposes the planet to be moved by a double motion, or one compounded of the harmonic circulation of its deferent fluid orb, and of a paracentric access to and recess from the sun. The circulation of the ether therefore makes the planet circulate harmonically, not by any motion of its own, but as it were by a perfectly quiet swimming in a deferent fluid, whose motion it obeys. Consequently neither retains an impetus of circulating swifter, than it had in an inferior or nearer orb, but one that languishes and lessens, as it passes through the superior (resisting a greater velocity than their own) till at last it insensibly accommodates itself to the orb it approaches; and on the contrary, while it moves from the superior to the inferior orbs, it receives their impetus. Consequently the harmonic proportion holds not only in arcs of circles, but in describing any other curve.

"For the area described in an element of time, cut off by radii drawn from the sun to the planet, moved in any other curve, doth not comparably differ from the sector of a circle, whose angle at the center is the same, and radius any one of the preceding.

"The other motion compounding with the former, the entire motion of the planet, (namely the paracentric,) arises from a double curve, namely, the *excussory impression of circulation and the sun's attraction* (or what is equivalent) compounded together. For since every body endeavours to recede from the curve line, it describes, along a tangent, by this motion alone, the planet carried by the vortex circulating harmonically, will recede from the sun. And these centrifugal forces are shewn by the author, to be reciprocally as the cubes of the radii. The other component part of the paracentric motion is the sun's attraction, or what supplies the place of it, the planets gravity: and though he calls this force attraction, he does not question but it is derived from the impulse of the ambient fluid, like the actions of the magnet.

"Because it is certain by observation, that each primary planet describes an elliptic orbit, in one of whose foci is the sun, so as that by radii drawn from the sun to the planet areas are always cut off proportional to the times; and there is no law of circulation in a vortex that answers this condition, but the harmonic: it remains that a law of gravity be sought after, that joined with the centrifugal conatus of the body circulating harmonically, may compose a paracentric motion, which in conjunction with an harmonic circulation makes the body to move in the perimeter of an ellipse, which (after the premising of a lemma shewing the ratio of a circulation in a conic section to the paracentric velocity) he defines, by demonstrating the following theorem: *if a heavy body be carried in an ellipse (or any other section of a cone) with an harmonic circulation, and the center both of attraction and circulation be in the focus of the ellipse; the attractions or solicitations of gravity will be as the squares of the circulations directly, or as the squares of the radii or distances from the focus reciprocally.*

"He has found therefore that there is such a thing as gravity in the planets, tending to the center of the sun, the law of which is, that it is reciprocally proportional to the squares of their distances from the center. And he farther acknowledges that this law was known before to Mr. Newton; his *Principles of Philosophy* being published before that time, and an account of them given in those Leipsic acts.

"After having annexed some corollaries naturally flowing from his chief theorem, he closes his physico-astronomical essay with a confession that there remained two things to be done on this argument: the one is to explain what motion of the ether it is, that makes the planets heavy, or impels them towards the sun, and that reciprocally as the squares of the distances, or (as he expresses it) as the squares of the vicinities: the other is, what is the cause of the comparison of the motions between the different planets of the same system, that the periodic times should be in the sesquialter ratio of the mean distances. And since (according to the author) they both ought to depend upon the contiguous bodies, all which he calls by the name of the ether, these two tend to explain more distinctly the motion of the vortex or ether that constitutes each system. But these things requiring a deeper search, and therefore not to be contained in so small a compass as a sheet, he says, it is more proper for him to publish his thoughts upon that matter separately."

Such is the theory of Leibnitz according to Dr. Gregory, who refutes it in the following manner, p. 177,

"There are some of the reasons against corporeal vortices carrying planets, that likewise make against the above-described essay of Leibnitz, *about the causes of the celestial motions;* namely, that the paths of some comets are very oblique to the zodiac, sometimes they cut this plane at right angles, nay, they are even directly contrary sometimes to the course of the planets. And since the comets (all the while they are observed by us) describe areas about the sun proportional to the times, by parity of reason, an harmonically circulating vortex ought to be supposed, such an one being as necessary for the motion of a comet as of a planet; that is, there ought to be one vortex contrary to another.

"In considering indeed but one planet carried about the sun (or any other centre) if it be to be carried by a vortex, without any proper motion of its own, only swimming quietly along in a deferent fluid, circulating harmonically, and obeying its motion, (which the author supposes;) the vortex ought to circulate harmonically, so as that the areas cut off by radii drawn from the planet to the sun, be proportional to the times. No other constitution of a vortex can make the ratio between the areas and times to be the same. If therefore the vortex of our author will not solve the motions of the planets, certainly no other will. And this being once supposed, all the rest, which our author draws from thence by geometry, proceeds very well and justly, as things usually do under his hand. To which I add, that such a vortex as this (whose fluid circulating harmonically in a plane through the center, to which the axe is perpendicular,) may be produced mechanically, by a solid sphere, if it be revolved in an uniform and infinite fluid, about an axe given by position, with an uniform motion, and the fluid be made to move round by the sole impulse of it, and every part of the fluid persevere in its motion uniformly. And this is a third thing, which remains for the author to explain concerning the motion of the solar vortex or ether; namely, how it might be impelled and put into an harmonic circulation. For, since universally the times of describing or running any space, are directly as the spaces run, and reciprocally as the velocities; and in a circular motion the spaces run in one revolution are as the radii, and in an harmonic circulation the velocities or circulations are reciprocally as the radii; it is evident, that the periodic times of the parts of a vortex circulating harmonically, are as the squares of the radii: but we have demonstrated* that this is the property of a circulation in a plane through the centre, to which the axis is perpendicular in the vortex, put into its motion by a central sphere.

"But, if the motions of two or more planets be compared together, it will appear, that the fluid matter of the solar vortex is not moved in an harmonic circulation. For we have already demonstrated that the periodic times of the parts of a fluid circulating harmonically (and consequently of bodies that are carried by a quiet swimming in the fluid) are as the squares of the radii. But the periodic times of the planets are not as the squares, or in the duplicate, but in the sesquiplicate ratio of the distances from the centre. And therefore different planets are not moved by an harmonic circulation.

"The author no doubt will say, that he did not suppose that the whole fluid of the solar vortex was moved by a continual harmonic circulation, no where interrupted, from Mercury to Saturn inclusively; but that the fluid carrying about Mercury moved in an harmonic circulation from its perihelium to its aphelium; then (this harmony being interrupted) again circularly harmonical from the perihelium of Venus to its aphelium, but not in an harmony continued with the former circulation near Mercury; that is, so as that the circulation of the fluid carrying Venus, is to the circulation of the fluid carrying Mercury, as the distance of Mercury from the sun, is to the distance of Venus from the same: and again, (the former harmony being interrupted,) the fluid carrying the earth is moved harmonically from the perihelium of the earth to the aphelium, if this harmony be considered solitarily, and not compared with the harmony of the fluid to Venus or Mercury; and so on in the other planets: that is, that by reason of the thickness of each orb, there holds a particular harmony separate and distinct from the rest; and in like manner in the Satellites of Jupiter and Saturn, ascending from the centre of Jupiter and Saturn. But it must be confessed, that the author does seem likewise to extend his harmonic circulation also to different planets, where he says:* *In double the distance, only a fourth part of the angle seen from the sun, is finished in the same element of time; in triple the distance only the ninth part:* for certainly these numbers have no place in the same planet. But if (as he ought principally to do) he speaks expressly concerning the interrupted harmony of the circulating parts of the fluid, he will hardly persuade philosophers that things are thus; namely, that by reason of the thickness of the orb of Mercury there is an harmonical circulation from the perihelium to the aphelium, or the velocities of the fluid are as the distances from the center reciprocally: but comparing this circulation with the circulation of the ether at any other planet, the one is to the other reciprocally as the squares of the radii: for we have demonstrated† independently of all physical causes, that the celerities of the planets are reciprocally as the square roots of their distances from the sun. Certainly the vortex of the sun would be monstrous, and these deferent fluid orbs more absurd than the deferent solid ones, if by reason of the thickness of each of the six deferent orbs the harmonic circulation has a place, and yet this harmony in the mean while is five times interrupted; namely, at the interstices of the deferent. And it makes contrary to this interruption, that a comet carried through the zodiac *in consequentia,* and passing through these interstices of the orbs carrying the planets, is moved just as if it were carried by an ether circulating harmonically; that is, so as that the areas described by the radius that carries it, are proportional to the times. It may be observed likewise, how difformly difform the solar vortex would be, in which the thickness of the orb of Saturn, where the harmonic circulation of the ether holds, is greater than the distance of Mercury from Venus, or of Venus from the earth, or of the earth from Mars, in every one of which the harmony is interrupted; and where, having laid aside the reciprocal ratio of the radii, which they keep in the harmony, the circulation of any two of these compared together, are reciprocally as the square roots of the radii, being about to resume the former harmony. The famous author himself seems to have discovered this fault of his harmonically circulating vortex, when he confesses, *that this likewise was one thing remaining,* namely, *to explain what should be the cause of the comparison of the motions between different planets of the same system, so as that the periodic times may be in the sesquiplicate ratio of the mean distances*: for he saw plain enough, that this could not be the effect of an harmonic circulation.

---

* Prop. 75.

---

* In par. 17. † In prop. 27 and 28.

"Perhaps some persons may wonder that Mr. Leibnitz, who deduced the motions of the planets from causes (at first sight) so different from those established before, should notwithstanding light upon the same law of gravity, whereby every planet is kept in its elliptic orbit. The reason of that coincidence is this: though Leibnitz makes use of the matter of a vortex circulating harmonically for carrying the planets about; yet, because in the planet thus carried about and describing any curve, he confesses an excussory conatus whereby a planet would be made to move in a right line touching the curve, if not hindered, he does the same as if he had made the planet to move equably in a right line, if not hindered: for these two motions together make it so; that is, all one as if it were carried in free spaces, acted upon by no external force at all. For in both cases it will describe a right line with an equable motion, for the body describing the right line with an equable motion runs in it after such a manner as* that the areas cut off by radii drawn to any given point, are proportional to the times. Since therefore the harmonic circulation and excussory conatus together perform the same as an equable motion in a right line does, he could not but find the law of gravity the same with that found out before; namely, that which would force the planet from the same right lined tangent which it would run after the same manner, into the same conic section towards the sun, posited after the same manner."

Having now presented to the reader the vortical theories of Kepler, Des Cartes, and Leibnitz, together with their refutations according to Dr. Gregory, we propose, in the next place, to present a very brief outline of the theory of Swedenborg; but before doing so we shall add the following remarks from Mr. Whewell's *History of the Inductive Sciences,* vol. ii., p. 198; which will inform the reader of the state of public opinion concerning the doctrine of vortices, from the time of Leibnitz and Newton to the period when Swedenborg published his *Principia.*

---

* By prop. 1, elem. 6.

"The reception of the Newtonian theory on the continent, was much more tardy and unwilling than in its native island. Even those whose mathematical attainments most fitted them to appreciate its proofs, were prevented by some peculiarity of view from adopting it as a system; as Leibnitz, Bernoulli, Huyghens; who all clung to one modification or other of the system of vortices. In France, the Cartesian system had obtained a wide and popular reception, having been recommended by Fontenelle with the graces of his style; and its empire was so firm and well established in that country, that it resisted for a long time the pressure of Newtonian arguments. Indeed, the Newtonian opinions had scarcely any disciples in France, till Voltaire asserted their claims, on his return from England in 1728: till then, as he himself says, there were not twenty Newtonians out of England.

"The hold which the philosophy of Des Cartes had upon the minds of his countrymen is, perhaps, not surprising. He really had the merit, a great one in the history of science, of having completely overturned the Aristotelian system, and introduced the philosophy of matter and motion. In all branches of mixed mathematics, as we have already said, his followers were the best guides who had yet appeared. His hypothesis of vortices, as an explanation of the celestial motions, had an apparent advantage over the Newtonian doctrine, in this respect;—that it referred effects to the most intelligible, or at least most familiar kinds of mechanical causation, namely, pressure and impulse. And above all, the system was acceptable to most minds, in consequence of being, as he pretended, deduced from a few simple principles by necessary consequence; and of being also directly connected with metaphysical and theological speculations. We may add, that it was modified by its mathematical adherents in such a way as to remove most of the objections to it. A vortex revolving about a centre could be constructed, or at least it was supposed that it could be constructed, so as to produce a tendency of bodies to the centre. In all cases, therefore, where a central force acted, a vortex was supposed; but in reasoning out the results of this hypothesis, it was easy to leave out of sight all other effects of the vortex, and to consider only the central force: and when this was done, the Cartesian mathematician could apply to his problems a mechanical principle of some degree of consistency. This reflection will, in some degree, account for what at first seems so strange;—the fact, that the language of the French mathematicians is Cartesian, for almost half a century after the publication of the *Principia* of Newton.

"There was, however, a controversy between the two opinions going on all this time, and every day showed the insurmountable difficulties under which the Cartesians laboured. Newton, in the *Principia*, had inserted a series of propositions, the object of which was to prove, that the machinery of vortices could not be accommodated to one part of the celestial phenomena, without contradicting another part. A more obvious difficulty was the case of gravity of the earth; if this force arose, as Des Cartes asserted, from the rotation of the earth's vortex about its axis, it ought to tend directly to the axis, and not to the centre. The asserters of vortices often tried their skill in remedying this vice in the hypothesis, but never with much success. Huyghens supposed the ethereal matter of the vortices to revolve about the centre in all directions; Perrault made the strata of the vortex increase in velocity of rotation as they recede from the centre; Saurin maintained that the circumambient resistance which comprises the vortex will produce a pressure passing through the centre. The elliptic form of the orbits of the planets was another difficulty. Des Cartes had supposed the vortices themselves to be oval; but others, as John Bernoulli, contrived ways of having elliptical motion in a circular vortex.

"The mathematical prize-questions proposed by the French Academy, naturally brought the two sets of opinions into conflict. The Cartesian Memoir of John Bernoulli, to which we have just referred, was the one which gained the prize in 1730. It not unfrequently happened that the Academy, as if desirous to show its impartiality, divided the prize between Cartesians and Newtonians. Thus in 1734, the question being, the cause of the inclination of the orbits of the planets, the prize was shared between John Bernoulli, whose memoir was founded on the system of vortices, and his son Daniel, who was a Newtonian. The last act of homage of this kind to the Cartesian system was performed in 1740, when the prize on the question of the tides was distributed between Daniel Bernoulli, Euler, Maclaurin, and Cavallieri; the last of whom had tried to amend and patch up the Cartesian hypothesis on this subject.

"Thus the Newtonian system was not adopted in France till the Cartesian generation had died off; Fontenelle, who was secretary to the Academy of Sciences, and who lived till 1756, died a Cartesian. There were exceptions; for instance, Delisle, an astronomer, who was selected by Peter the Great of Russia, to found the Academy of St. Petersburg; who visited England in 1724, and to whom Newton then gave his picture, and Halley his Tables. But in general, during the interval, that country and this had a national difference of creed on physical subjects. Voltaire, who visited England in 1727, notices this difference in his lively manner. 'A Frenchman who arrives in London, finds a great alteration in philosophy, as in other things. He left the world full, he finds it empty. At Paris you see the universe composed of vortices of subtile matter, at London we see nothing of the kind. With you it is the pressure of the moon which causes the tides of the sea, in England it is the sea which gravitates towards the moon; so that when you think the moon ought to give us high water, these gentlemen believe that you ought to have low water: which unfortunately we cannot test by experience; for in order to do that, we should have examined the moon and the tides at the moment of the creation. You will observe also that the sun, which in France has nothing to do with the business, here comes in for a quarter of it. Among you Cartesians, all is done by an impulsion which one does not well understand; with the Newtonians, it is done by an attraction of which we know the cause no better. At Paris you fancy the earth shaped like a melon, at London it is flattened on the two sides.'

"It was Voltaire himself, as we have said, who was mainly instrumental in giving the Newtonian doctrines currency in France. He was at first refused permission to print his *Elements of the Newtonian Philosophy*, by the chancellor, D'Aguesseaux, who was a Cartesian; but after the appearance of this work in 1738, and of other writings by him on the same subject, the Cartesian edifice, already without real support or consistency, crumbled to pieces and disappeared. The first Memoir in the transactions of the French Academy, in which the doctrine of central forces is applied to the solar system, is one by the Chevalier de Louville in 1720, *On the Construction and Theory of Tables of the Sun*. In this, however, the mode of explaining the motions of the planets by means of an original impulse and an attractive force is attributed to Kepler, not to Newton. The first Memoir which refers to the universal gravitation of matter is by Maupertuis, in 1736. Nor was Newton unknown or despised in France till this time. In 1699 he was admitted one of the very small number of foreign associates of the French Academy of Sciences. Even Fontenelle, who, as we have said, never adopted his opinions, spoke of him in a worthy manner, in the *Eloge* which he composed on the occasion of his death. At a much earlier period too, Fontenelle did homage to his fame. The following passage refers, I presume, to Newton. In the *History of the Academy* for 1708, which is written by the secretary, he says,* in referring to the difficulty which the comets occasion in the Cartesian hypothesis: 'We might relieve ourselves at once from all the embarrassment which arises from the directions of these motions, by suppressing, as has been done *by one of the greatest geniuses of the age,* all this immense fluid matter, which we commonly suppose between the planets, and conceiving them suspended in a perfect void.'

"Comets, as the above passage implies, were a kind of artillery which the Cartesian *plenum* could not resist. When it appeared that the paths of such wanderers traversed the vortices in all directions, it was impossible to maintain that these imaginary currents governed the movements of bodies immersed in them; and the mechanism ceased to have any real efficacy. Both these phenomena of comets, and many others, became objects of a stronger and more general interest, in consequence of the controversy between the rival parties; and thus the prevalence of the Cartesian system did not seriously impede the progress of sound knowledge. In some cases, no doubt, it made men unwilling to receive the truth, as in the instance of the deviation of the comets from the zodiacal motion; and again, when Römer discovered that light was not instantaneously propagated."

We have now traced the course of the doctrine of vortices down to the period in which Swedenborg took up the subject in his *Principia,* in the year 1743.

Let us in the next place proceed to state the particular theory of Swedenborg.

There are two ways in which the natural world may be made the subject of investigation. We may begin with the first cause, thence descend to secondary causes, and thence continue downward to the ultimate effect. On the other hand we may begin with the ultimate effect, and thence ascend through the series of secondary causes up to the first cause. The first method of investigation is the one adopted in the First Part of the *Principia,* and is called the synthetical; the second method is introduced in the Second Part of the *Principia* in order to test the truth of the first method, and is called the Newtonian or inductive.

Now the first cause is the infinite, or unfinited, or unlimited; the secondary causes are the first finited or limited, the second finited or limited, &c. Hence we have the series, no limit, one limit, two limits, three limits, &c. That which is first produced by the unlimited, is that which has only one limit; but that which has only one limit is indivisible because it has no parts, and can be resolved into nothing more simple than itself. That in the unlimited which produces a limit is analogous to motion; the limit produced is a point the essence of which consists in motion. This motion is pure and total, or universal, and universal motion is not motion in act but in conatus to act.*

---

* Hist. Ac. Sc. 1708, p. 103.

Swedenborg however observes, p. 57, Vol. I.:

> "How then are we to conceive of this purity and totality in motion? Certainly in no other way, if geometrically and rationally understood, than as an internal state, or effort [*conatus*] to motion. For if in the whole motion there be no degrees, no moments, and thus no celerity; and if again there be nothing substantial, as before observed; what else, according to every human notion or idea, can result thence, but effort or *conatus?*"

The first natural point being without parts, and yet being endowed with conatus, is not extended but creates extension, has no space but creates space, possesses no figure but creates figure, exercises its conatus in no succession of time but creates time; and whereas in fluxional geometry a point produces a line, a line a surface, and a surface a solid, so that all the figures produced may be said to arise out of the geometrical point and to be contained within it, so likewise in the first natural point which is conatus to motion, in other words, effort or internal state, are contained as *in ovo* all the motions of the universe which are afterwards developed out of it. Having however as yet only one limit, and consequently no parts, it is susceptible of no ratios, and cannot be made the subject of any investigation, nor can anything be predicated of it except in the way of analogy.

The point although it has no figure has a conatus to figure, because it has a conatus to motion. Motion produces space, and figure is the quality of space, and the figure to which the point has a conatus is the spiral.

Now, observes Swedenborg, p. 63, Vol. I.:

> "*Since this motion*, in which the point consists, *is a conatus tending to actual motion, or what amounts to the same thing, since it is pure*

---

* See the *Cosmology* of Christian Wolff, art. 174.

motion, not existing in any medium of finites, but in the Infinite, *its figure must necessarily be most perfect. Pure motion, or motion in the Infinite, cannot produce anything imperfect, or unequal: but whatsoever is produced by it must be in all respects most uniform and perfect. If the figure of the motion be most perfect, it must necessarily resemble a circular figure,* than which nothing in the nature of finite things can be more perfect. But since the point consists purely of motion, insomuch that this point, and pure motion, and a conatus tending to motion, are one and the same thing, it follows, that motion must exist everywhere in the point. *If the most perfect figure be circular,* then the most perfect figure of the motion above described must be the *perpetually circular;* that is to say, it must proceed from the centre to the periphery, and from the periphery to the centre."

Again, p. 66, Vol. I.:

"Since then total motion, or that which is internal, tends to a figure most perfectly and purely mechanical, that is, to the spiral, we hence obtain an idea of the internal state of the point; by which internal state we perceive the quality of the conatus, as it presses forward into external motion. The real determination and direction of active or local motion is alone owing to the figure by which this conatus exists. It was before observed, that the figure is perpetually spiral, proceeding from the centre to the periphery, and reciprocally from the periphery to the centre; by and according to which figure it is inclined to direct every effort, and as it were to aspire to active and local motion. For if there be a conatus tending to motion, and if a similar quality exist in conatus as in motion, then by virtue of that similitude there must exist figure and space. For example, if there be a conatus tending directly from one extremity to the other, a rectilinear motion will ensue in that direction: but if the conatus, by the figure which it assumes, revolve round a kind of centre, in this case a circular motion will be the result. Not only does the motion receive its determination, but also its direction, from conatus; and thus whatsoever does or can exist in motion, is previously to be found in conatus. The figure therefore in conatus, of which the simple ens consists, agreeably to what has been already advanced, is spiral. From the figure we are now authorized to conclude as to the kind of motion into which the conatus runs. *I say then, from the mechanism and geometry of the internal spiral motion there arises a kind of axillary motion; afterwards a progressive motion of all the spiral circles round their poles; and lastly, from the axillary and progressive motion, if there be full liberty, and no impediment in contact with it, another or local motion in agreement with* *the former, and indeed tending into perpetual surfaces.* But as these subjects cannot be geometrically treated, and still less demonstrated, without having recourse to some finite body or corpuscle, consisting of parts and individual substances; and in which those parts and individual substances are arranged into a situation and spiral figure, like those which the conatus assumes in the point; so by the method here proposed we shall be able to obtain a mechanical and ocular demonstration, that such a situation or disposition of the parts or individual substances begets and produces not only a common axillary motion, but also a progressive motion, conformable to the situation and series of the spiral curves; and in addition to this, provided there be full liberty, and no immediate impediment in the way, a second or local motion, by which the surfaces or external particles receive their figure. As the point consists not of parts, it cannot so well undergo geometrical examination, explanation, investigation, and dissection: we shall therefore proceed to the consideration of finites and actives, in which the mechanism of the same motion will be gradually presented to view. We shall afterwards demonstrate by experience, and likewise by the laws of mechanism, that in the point, or in the conatus of the point, lies concealed the whole power, both active and passive, of mechanically producing, in just order and in regular succession, all finites whatsoever, or the world at large, as well with respect to its smaller and simple parts, as to its greater and composite. *Geometry, therefore, and mechanism, in relation both to the parts and to the whole of a body, and also in relation to the world itself, consists in this, that the first figure of motion, state, and conatus, is spiral; and that by virtue of such a figure there succeed a motion of the whole composite, or an axillary motion; a motion of its parts, or a progressive motion: and lastly, from or by virtue of these, a local motion. Such is the sum of our whole work and of its principles; and such the cause of all the parts and compositions in our mechanical world.*

Again, p. 84, Vol. I.:

"It is evident, I think, that if internal motion be granted, it must, for the alleged reasons, be spiral. But if the spiral motion be continual, it must be reciprocal. Without a reciprocation, it could not be continual. Nothing can spirate continually unless it spirate reciprocally. Without a reciprocal anhelation there is nothing continual; for there would be no fluxion from the centre to the circumference, if there were no reflux from the circumference to the centre; in fine, the very continuation of motion consists in reciprocation and alternation. If, therefore, there be reciprocation and if the motion be spiral, we cannot conceive of such a motion taking place mechanically, unless a figure be conceived of such a kind as will admit of this flux and reflux of motion; nor even then could such a flux and reflux take place, unless in this figure *loci* were conceived on all sides, through which any point flowing to the surface might afterwards return. Unless in the figure such *loci* could be assigned, one point in its fluxion would encounter another; a single point would thus act as a cause of retardation and quiescence to another, whence all motion would cease. If, however, there be a regular reciprocation, then must there be on all sides in the figure of motion, *loci* through which the points may always return to the centre; thus there must also be a way from the centre to the circumference and from the circumference to the centre, lest one point should encounter another. If, therefore, a reciprocal spiral motion be granted, it must be granted also, that, in the space thus comprehended, there must on all sides exist *loci* through which a reflux and reciprocation may take place.

"*That from the motion of the points, parts, or individuals, arises the genuine and constant situation of all. Consequently, that in a finite, by reason of the spiral motion and situation of its parts, there arise two poles, one opposite to the other; and that these two poles are formed like cones.* Motion always precedes site or situation. Without motion there would be no disposition of parts. It is only by motion that parts are united into a disposition conformable to the motion and its figure. It is by motion that parts tend to an equilibrium. Motion therefore adapts the figure to the situation or disposition. Such as is the cause, such is the effect. It is thus that the parts remain permanent in the situation into which they ultimately come in consequence of their motion. Now since the disposition or situation of the parts is the figure of the motion, it follows, that in this situation all the parts continue to spirate, and exercise an effort to motion according to the internal force remaining in each individual. Already the parts are in such a situation, that they all spirate similarly toward the same motion, and act simultaneously as one common cause; so that there is no part which is not necessary, and which is not a part of the motion, and which does not contribute its own share to the general motion. One part consequently maintains a relation to the other; the adjacent, both to the adjacent and to the remote; the superficial, to the intermediate; the intermediate, to the central; the central, to the superficial; and so on through a regular circle. Hence every part is in series and connexion; the motion of one can be the motion of all as well as of itself; and this in a circle. Such a situation of the parts can be obtained only by means of the spiral. The communication and the reciprocation of motions, the circulation of whatever kind, when the parts are brought into a regular situation, are obtained by means of poles, whence there is a chain of connexion, contiguity, and motion, extending from one pole to another; so that the motion can, as it were, pass out of one pole and enter into the other, and thus pass and repass by continuous circles and perpetual spires. The fact that, in such a motion or situation of the parts, the poles become, by reason of the mechanism of the motion and the geometry of the figures, formed like cones, will be explained in the sequel.

"*That, in like manner, in every finite ens, whose parts are disposed into a spiral figure, there are an equator, ecliptic, meridians, and other perpendicular circles.* If there are poles, and if those poles be divaricated and enlarged into the figure of a cone, then there will be also polar circles, the dimension of which is the diameter of the cone. If there are cones and polar circles, there is an equator equidistant from the poles, together with meridians running perpendicularly through it from one pole to another. If the spiral figure be on the surface, as well as in the interior circles, then there are circles of latitude formed by the spires in the surface; and if these are bisected at right angles, the ecliptic will pass through the sections. Thus do the poles form the meridians and equator; while the spires form circles of latitude and the ecliptic; thus also begins the same order in the microcosm which we see in the macrocosm, and thus the same, nearly at least, takes place in the smallest figure as in the largest, or in that of the world; for even in the larger, before the figures are developed, they are more inflected and incurvated. All these relations originate solely from the spiral motion. That it is in these things that consists the power [*vis*] and quality of producing a world, such as we contemplate and such as our senses perceive, or, in other words, of advancing the process of its formation to that end in which its phenomena can be placed before us geometrically, or in a manner conformable to its mechanism, will appear in the sequel."

Again, p. 89:

"To avoid dwelling upon mere effects and causates, and too long deferring the consideration of causes, it will be necessary to premise *what is that thing in act, or that active force, in a point or finite, which, by a* vis insita, *produces this mutual motion.* This subject is of main importance. We have affirmed that, in internal motion, or intrinsically in a simple or individual part, there is inherent and permanent a power of putting itself in motion; and, by means of this, a power of finiting or limiting some new aggregate. Unless this power were in the individual parts respectively, they never could dispose themselves into a spiral, or into their figure of motion. Without such a power [*vis*] and quality, the points would, with all their general axillary and progressive motion, remain inert; one would not act upon the next adjacent, but would each be destitute of all determination and direction. As however we are now treating of points, these observations are introduced only by way of anticipation; for geometry is scarcely capable of entering into the analogy and ratio of a pure motion, or that which is in the simple. If there be a spiral figure, that figure must have a centre. The centre of a spiral cannot be in the same place with the centre of a circle; for a spiral is continually removing itself from the centre, and receding from the circle. The centre of the spiral must therefore be at a distance from the centre of the circle. If the fluxion of the parts be spiral, then the centre of the parts spirally moved or arranged, is not in the centre which is in the middle of the corpuscle, but in one which is at some distance from it. Hence the centre of gravity is not in the middle, but is near the middle of the corpuscle, individual, or point. Let us, therefore, suppose the centre of gravity to be at a distance from the centre of the equator or outermost circle, and at the same time also from the axillary motion; it will follow, that, by the axillary motion, the centre of gravity also is rotated into the same motion, and the corpuscle becomes the most highly active at the point in which we find its centre of gravity, whence it becomes like an actual or active force [*tanquam actuale fit*]. The axillary motion being thus a motion in act [*actualis*] imparts to the centre of gravity the power [*vis*] and conatus of giving a direction to the whole corpuscle in accordance with itself and its figure; that is to say, into a second motion or into a figure of motion the same with its own. Conceive a corpuscle rotating round an axis, and the centre of this corpuscle gravitating not in the axis but near it; in this case, by means of the axillary motion, the centre gravitates in that direction in which it rotates with the axis; that is to say, it gravitates into a circle, together also with the axillary motion. But inasmuch as there is a progressive motion, in which the figure and situation of all the parts is preserved, it follows, that the centre of gravity also must continually observe the same motion and figure of motion. For if the figure and situation of the parts be preserved, and if nevertheless the motion of the parts be progressive, then, in this situation of the parts so preserved but at the same time in motion, the corpuscle progresses in like manner as the centre of gravity; and consequently directs its circular gyration into a conformity to its own situation and motion; that is to say, not only into a circle, but into a certain superficies; inasmuch as this centre moves only one step, while the axillary or common motion performs an entire circle. In fine, if the centre of gravity be not in the centre of the outermost circle, that is to say, in the centre of the corpuscle, but only at some distance from it; and if the corpuscle rotate round its axis; it follows, that the centre of gravity is perpetually impelling the corpuscle to a motion extraneous to itself and circular. And further, if the motion of this centre be progressive, it follows that it endeavours to bring into the same figure of progressive motion (that is to say, a superficial figure) the whole of the corpuscle that is in motion."

Again, p. 94:

"We see that the motion of the free and elementary parts tends to a certain spiral gyration; that all mechanical power is inherent in this motion, and owing to it. We see the solar vortex itself tending to flow into a similar gyre, and forming by a fluxion of this kind larger and smaller circles, also ecliptics, equators, meridians, and all the other circles belonging to the earth and the heavens; imitating on a large scale the modes of the smaller and simple; or else, the simpler and smaller imitating the motion of the compounded and larger. That there is a certain situation of parts according with these circles, is manifest in the universe at large and from innumerable evidences presented by the different bodies which flow among these particles or in any volume of these particles. In a word, the whole visible world appears to be full of proofs, that the general situation of its parts is in accordance with certain circles of the world; the consequence of which is, that the very parts which cause this general situation are themselves of a similar character."

To enter more particularly into the mechanism of the actives, finites, and first element, would be inconsistent with the present object of the translator, which is only to present such a general view of the subject as may enable the reader to compare it with the theories propounded by other authors.

In the foregoing remarks of Swedenborg we may observe two things; first, the system of corpuscular philosophy; secondly, the theory of vortical motions which is founded upon it. Now with regard to corpuscular philosophy, Christian Wolff remarks in his *Cosmology*, art. 230, "that philosophy is called corpuscular which derives the reason of phenomena from corpuscles;" and he adds that in his day, 1737, scarcely any natural philosopher of any authority could be found who did not subscribe to it. Without going into the system of corpuscular philosophy propounded by Leibnitz, we may observe that the first natural point of Swedenborg so far agrees with the monad of Leibnitz that the essence of both is regarded as consisting in motion, hence in force, consequently both are considered as endowed not with a *vis inertiæ,* but with a *vis insita :* moreover both the *monad* of Leibnitz and the *point* of Swedenborg are regarded as immaterial. As to Kepler's immateriated species of substance, Mr. Whewell observes in his *History of the Inductive Sciences,* Vol. II., p. 130:

"I think it will be found, by any one who reads Kepler's phrases concerning the *moving force,—the magnetic nature,—the immaterial virtue* of the sun, that they convey no distinct conception, except so far as they are interpreted by the expressions just quoted. A vortex of fluid constantly whirling round the sun, kept in this whirling motion by the rotation of the sun himself, and carrying the planets round the sun by its revolution, as a whirlpool carries straws, could be readily understood; and though it appears to have been held by Kepler that this current and vortex was immaterial, he ascribes to it the power of overcoming the inertia of bodies, and of putting them and keeping them in motion, the only material properties with which he had anything to do."

We have already observed that, according to the theory of Swedenborg, there is no *vis inertiæ* to be overcome. We may here add Sir Isaac Newton's theory of corpuscular philosophy, as derived from his *Optics,* p. 375 : thus enabling the reader to compare it with that of Swedenborg.

"All these things being considered, it seems probable to me, that God in the beginning formed matter in solid, massy, hard, impenetrable, moveable particles, of such sizes and figures, and with such other properties, and in such proportion to space, as most conduced to the end for which he formed them; and that these primitive particles being solids, are incomparably harder than any porous bodies compounded of them; even so very hard, as never to wear or break in pieces; no ordinary power being able to divide what God himself made one in the first creation. While the particles continue entire, they may compose bodies of one and the same nature and texture in all ages: but should they wear away, or break in pieces, the nature of things depending on them, would be changed. Water and earth, composed of old worn particles and fragments of particles, would not be of the same nature and texture now, with water and earth composed of entire particles in the beginning. And therefore, that nature may be lasting, the changes of corporeal things are to be placed only in the various separations and new associations and motions of these permanent particles; compound bodies being apt to break, not in the midst of solid particles, but where those particles are laid together, and only touch in a few points.

"It seems to me farther, that these particles have not only a *vis inertiæ*, accompanied with such passive laws of motion as naturally result from that force, but also that they are moved by certain active principles, such as is that of gravity, and that which causes fermentation and the cohesion of bodies. These principles I consider, not as occult qualities, supposed to result from the specific forms of things, but as general laws of nature, by which the things themselves are formed; their truth appearing to us by phenomena, though their causes be not yet discovered. For these are manifest qualities, and their causes only are occult. And the Aristotelians gave the name of occult qualities, not to manifest qualities, but to such qualities only as they supposed to lie hid in bodies, and to be the unknown causes of manifest effects: such as would be the causes of gravity, and of magnetic and electric attractions, and of fermentations, if we should suppose that these forces or actions arose from qualities unknown to us, and incapable of being discovered and made manifest. Such occult qualities put a stop to the improvement of natural philosophy, and therefore of late years have been rejected. To tell us that every species of things is endowed with an occult specific quality by which it acts and produces manifest effects, is to tell us nothing: but to derive two or three general principles of motion from phenomena, and afterwards to tell us how the properties and actions of all corporeal things follow from those manifest principles, would be a very great step in philosophy, though the causes of those principles were not yet discovered. And therefore I scruple not to propose the principles of motion above mentioned, they being of very general extent, and leave their causes to be found out.

"Now by the help of these principles, all material things seem to have been composed of the hard and solid particles above mentioned, variously associated in the first creation by the counsel of an intelligent agent. For it became him who created them to set them in order. And if he did so, it is unphilosophical to seek for any other origin of the world, or to pretend that it might arise out of a chaos by the mere laws of nature; though being once formed, it may continue by those laws for many ages. For while comets move in very eccentric orbs in all manner of positions, blind fate could never make all the planets move one and the same way in orbs concentric, some inconsiderable irregularities excepted, which may have risen from the mutual actions of comets and planets upon one another, and which will be apt to increase till this system wants a reformation. Such a wonderful uniformity in the planetary system must be allowed the effect of choice."

In 1759, Boscovich published his celebrated theory of the *Constitution of the Universe,* and in 1788, Mr. Robert Young published his *Essay on the Powers and Mechanism of Nature,* intended by a deeper analysis of physical principles to extend, improve, and more firmly establish the grand superstructure of the Newtonian system. In this work the author observes, p. 64:

"The doctrine maintained by Locke, is, that matter actually exists, solid, inactive, extended, figured and moveable, and these qualities are considered as primary and essential; but that it is in itself destitute of colour, flavour, odour, sound, and feeling; these, called secondary qualities, being said to exist only in our perception, and to be produced in us by the operation of the primary qualities.

"Another doctrine published at Venice in the year 1763, by M. Boscovich, said to have been first thought of by Mr. Mitchell, and lately defended by Dr. Priestley, is, that matter is penetrable, and consists only of centres surrounded, at different distances, with spheres of attractive and repulsive powers, being unsolid and essentially active.

"Berkley carried his abstraction still further, and argued that there was no intermediate agency between our minds and the Supreme Mind; that the world had no real being but in the reality of our ideas, and in the perception of the supreme mind which communicates them to us.

"Of the first of these, which corresponds with the Newtonian philosophy, it is not necessary to add anything here to what is contained in the preceding chapters.

"The two latter agree that nothing INERT exists in nature, but differ, in that one admits secondary active powers; while the other allows of no *mediate* instrument, but refers all our ideas *directly* to the volition of Deity.

"The former of these two answers in general to the opinion here maintained," &c.

Mr. Young moreover maintains, p. 229, that "motion is the primordial state of creation, which it cannot lose without ceasing to be;" and p. 327, that "motion is the original state of being." Again he observes, p. 152:

"When any compound is resolved into its component principles, those principles have separately each a different nature from the compound which they form when united, and require each to be marked by a different name.

"We must be careful here to discriminate between the division of wholes into parts, and the separation of compounds into principles; a half, fourth, tenth, or any fractional part, has the same nature with the whole and differs only in quantity; for this sort of division has no respect to the qualities of things, but to their relative quantities only. But when a certain nature or quality belonging to any body, is produced from the union of several other bodies, each of different qualities, here arises a ground of division of a different sort, which has no regard to quantities, wholes, or parts, but merely to the qualities of things; and when a single substance results from a union of two or more, the separation of those things, thus united, reproduces the original and separate substances, while it destroys the compound which existed only in their union. Wine, *e.g.* is a compound liquor, produced from a union of several other things, neither of which, of themselves, are wine. On distillation, a pure spirit, water, and earth, are found to have been united in the compound wine. The separation of these destroys the wine, and gives rise to the distinct existence of the spirit, earth, and water. The separation of these is altogether different from a division of the wine, as it respects quantity; for we may divide a portion of wine indefinitely into smaller quantities, while each divided portion shall still be wine, because it retains in union the three principles, water, spirit, and earth.

"We may, therefore, to preserve these different sorts of divisions distinct, call the division that has respect merely to quantity, a separation of parts; the other, which has respect to qualities, a separation of principles or elements; those more simple things, which by union form a more compound, being usually denominated the principles or elements of the compound.

"The latter of these methods of division answers also to the terms analysis, resolution, or decomposition. And this, chemistry practically applies to particular genera or species of bodies, as minerals, vegetables, spirit, oil, salts, &c., to discover the more simple principles of these compounds, and again to those principles as themselves compounds, to arrive at their principles. But to matter in the general, as a solid extended substance, not distinguished into this or that particular kind, this sort of analysis has never, that I know of, been applied. Matter has been conceived as being capable of a division only into *parts* continually less and less, each part still being matter, but not of a decomposition into *principles* of a different nature from matter.

"If we consider matter in its general nature, as a compound formed of more simple elements, these elements must differ from matter, as the elements of wine, spirit, earth, and water, differ from wine. These have not the qualities of wine, and therefore do not answer to the definition of the term wine; so in like manner the separate elements of matter, if there be any such, cannot answer to the definition of matter; they cannot separately have the properties of matter, because these properties arise from their union only: these elements therefore cannot be matter, and, not being matter, must necessarily be immaterial."

Some of the systems of corpuscular philosophy which have been propounded by modern philosophers in opposition to the atomic theory of Epicurus, regard the original corpuscle as endowed with an innate activity, or according to Swedenborg, with a conatus to it; others consider it as inert; and upon this difference of constitution of the original, monad, atom, point, or whatever it be called, depends the difference of the vortical theory founded upon it; in the one case the vortical fluid being considered to be inert, and put into motion from without; in the other the vortical fluid being considered to be active, and put into motion from within, which is the doctrine of Swedenborg as distinguished from that of others.

Although Kepler regarded the vortical medium as the immateriated species of the sun's body, and consequently as not consisting of mere inert material particles, yet he supposed the planet to swim in this medium as a vessel is borne upon the water; so that although the vortical medium was not regarded as inert, yet the planetary body was; whereas according to Swedenborg, the planetary body has inherently a conatus to motion in consequence of being compounded of the same kind of particles as those of which the vortex consists.

With regard to the theory of Des Cartes, he considered both the vortices and the planets to consist of matter, and matter being considered to be inert, in order to renew the lost activity he was obliged to have recourse to an immediate supernatural interposition.

With regard to the theory of Leibnitz, notwithstanding his theory of the constitution of the monad, he seemed to conceive the planet to circulate not by the aid of any conatus of its own, but by a quiet swimming in the deferent fluid whose motions it obeys.

A similar kind of vortical medium it is that Sir Isaac Newton supposes in his *Mathematical Principles of Natural Philosophy,* vol. 2, p. 413, Scholium, and upon which he partly founds his objections to the existence of vortices,—objections which seem to be inapplicable to self-moving vortices. It must be owned, however, that there are other principles upon which the vortical theory has been said to be overthrown, and which have been maintained by far the larger class of natural philosophers.

The general argument against the doctrine of vortices as professedly derived from the principles of Sir Isaac Newton, is stated by Mr. Cotes, in his *Preface to the Mathematical Principles of Natural Philosophy;* and as the objections alleged are meant to subvert *all vortical theories whatsoever,* it is desirable upon the present occasion that they should be briefly noticed.

First then Mr. Cotes observes, p. 42 *(Thorpe's Ed.)*:

> "That every body perseveres in its state of rest, or of uniform motion in a right line, till it is made to change that state by some external force impressed, is a law of nature universally admitted by philosophers. But thence it follows, that bodies moving in curve lines, which are continually bent from the tangents of their orbits, are retained in their curvilinear path by some force constantly acting. Since then the planets revolve in curvilinear orbits, there must necessarily be some force, by whose incessant actions they continually deviate from the tangents."

Here we see the difference between Inductive Science and Corpuscular Philosophy; the former beginning with effects, the latter, with causes; the former, with bodies acting in mass; the latter, with the corpuscles constituting the mass; the former, with the external motions of the mass; the latter, with the internal motions of the corpuscles constituting the mass. Mr. Cotes has not observed this difference, and consequently speaks of bodies at rest, of external forces, of motions in straight lines, of curvilinear motions being produced by the composition of rectilinear, and hence of consequent tendencies in bodies to fly off in the directions of tangents. This view of the subject is perhaps the only one which is proper to the method of investigation laid down by Newton; but if this method be altered, the whole question is altered, and it becomes as absurd in a true system of corpuscular philosophy to talk of uniform motions in a right line, of external forces, and tendencies to fly off in a tangent, as it would be for a chemist to explain upon these principles the effervescence produced by the mixture of an acid and an alkali.

But secondly, Mr. Cotes observes, p. 49:

> "It is the business of true philosophy to derive the nature of things from causes which really exist: to investigate those laws which the great Creator hath thought proper to establish for the regulation of the most beautiful order of things; not those which he might have established for the same ends, if he had so appointed. For it is agreeable to reason to suppose, that the same effect may arise from various causes: but that will be the true cause, from which it really, and in fact, proceeds; the others have no place in true philosophy. The same motion of the index of a clock may be produced, either by a weight suspended, or by the action of a spring. But if it should be proposed to account for the motion of a clock, which is really moved by a weight; that man would justly be laughed at, who should first suppose a spring, and from that imaginary hypothesis should undertake to explain the motion of the index: for he ought first to examine the real internal construction of the machine, and thence explore the true principle of the proposed motion. A similar judgment should be passed upon those philosophers, who suppose that the celestial regions are replete with a very subtile matter, which is continually carried round in vortices. For, if they could explain the phenomena ever so accurately from their hypotheses; yet they can never be said to have discovered true philosophy, and to have found out the real causes of the celestial motions; unless they shall demonstrate either that those causes really exist, or at least that no other do exist. If therefore it has been shewn, that the universal gravitation of matter is really established in the nature of things; and if it has been explained also, in what manner all the celestial motions may thence be solved; it will be vain and ridiculous for any one to object, that these motions ought to be accounted for by vortices, even though we should allow that it was possible. But in reality the phenomena of nature cannot be explained by vortices; which our author has abundantly proved by the clearest reasoning."

Mr. Cotes here and elsewhere asserts that there is no proof of any existence of a subtile matter in the celestial regions. To this it may be sufficient to reply that since the period in which he wrote, considerable advances have been made in astronomical science, and we shall see in the sequel that a subtile matter or ether of some kind is now generally supposed to exist. But Mr. Cotes intimates that even if it does, and the existence of vortices could be proved, it would be unnecessary, as the doctrine of gravitation is sufficient to solve every phenomenon. But to this it may be replied that if the existence of vortices can be proved, and the doctrine of gravitation at the same time can be proved, then the coexistence of the two would shew that there is not that repugnance between a true theory of vortices and a true doctrine of gravitation which Mr. Cotes supposes: vortices moreover would have their place in inductive science just the same as any other fact, which we should be at no liberty to reject because we could not fully comprehend it.

But thirdly, Mr. Cotes observes, p. 50:

> "If the bodies of the planets and comets are carried round the sun by vortices, the revolving bodies, and the nearest ambient parts of the vortices, must be moved with the same velocity, and in the same direction; and must have the same density, and the same inertness, in proportion to the bulk of the matter. But it is evident, that the planets and comets, when they are in the same parts of the heavens, are moved with various velocities, and in various directions. It necessarily follows, then, that those parts of the celestial fluid, which are at the same distances from the sun, must revolve at the same time in different directions with different velocities: for one direction and velocity will be required for the motions of the planets, another for the motions of the comets. And since this cannot be accounted for, it must either be confessed that all the celestial bodies are not carried round by a vortical matter; or else that their motions are to be derived, not from one and the same vortex, but from several distinct ones, pervading the same space round the sun."

If these observations be applied to the system of Swedenborg, it might be urged that the author has not taken into consideration the difference between cometary and planetary matter. Cometary matter being much less condensed, its constituent particles have a freer action, and are therefore more capable of acting according to their interior conatus, irrespectively of the medium in which they move. It must be owned however, that Swedenborg has made no reference to the subject of comets, nor were the retrograde motions of the satellites of Uranus then discovered; so that upon this subject the reader will have to form his own opinion; remembering at the same time that notwithstanding these circumstances, the probabilities of the existence of a vortex of some kind or other are thought to be so great, that in the present day the difficulties above-mentioned are considered as rather phenomena awaiting solution, than as positive objections.

Speaking of Biela's comet, Sir J. Herschell observes in his *Treatise on Astronomy,* p. 310:

> "Should calculation establish the fact of a resistance experienced also by this comet, the subject of periodical comets will assume an extraordinary degree of interest. It cannot be doubted that many more will be discovered, and by their resistance questions will come to be decided, such as the following:—What is the law of density of the resisting medium which surrounds the sun? Is it at rest or in motion? If the latter, in what direction does it move? Circularly round the sun, or traversing space? If circularly, in what plane? It is obvious that a circular or vorticose motion of the ether would *accelerate some comets and retard others,* according as their revolution was, relative to such motion, direct or retrograde. Supposing the neighbourhood of the sun to be filled with a material fluid, it is not conceivable that the circulation of the planets in it for ages should not have impressed upon it some degree of rotation in their own direction. And this may preserve them from the extreme effects of accumulated resistance."

Fourthly, Mr. Cotes observes, p. 50:

> "If several vortices, contained in the same space, are supposed to penetrate each other mutually, and to revolve with different motions; because these motions ought to be conformable to the motions of the bodies produced by them, which are perfectly regular, and are performed in conic sections of different forms, some very eccentric, and some approaching nearly to the form of circles, it may reasonably be asked, how it is possible, that these vortices should be preserved entire for so many ages, without suffering any pertubation from the collisions of the matter moving in contrary directions. If these fictitious motions are more compounded, and more difficult to be accounted for, than the true motions of the planets and the comets, it seems in vain to admit them into philosophy: for every cause ought to be more simple than its effect."

To this it may be replied, that if the motion of the fluid were produced by extraneous causes, the objection might in some measure apply; but it is inapplicable where the motions of the particles are produced by a conatus from within; for in this case, even supposing two particles to encounter each other with equal force and thus to suspend their motions, yet immediately upon their being free they resume them. Besides, according to Swedenborg, every particle of magnetic effluvium has a vortical motion, and in addition to this, is encompassed with its own proper sphere, which has likewise a vortical motion, and prevents its coming into contact with the particles of iron. Otherwise we might ask upon the principles of Mr. Cotes how is it possible that the magnetic fluid flowing through the earth, or through hard iron, should have continued to encounter these solid bodies for so long a time without having its current impeded; or again, how it is possible that two magnetic currents of equal force encountering each other, should not give rise to a state of rest or equilibrium of the effluvial particles. With regard to the *true* motions of the comets and planets, perhaps no mortal can as yet say what they are; it is only their relative motions which are the subject of astronomy, and motion in a straight line may be as much compounded as motion in a curve. According to the principles of the corpuscular philosophy, the error which invalidates Mr. Cotes' reasoning against vortices, arises from not observing the difference between two methods of investigation essentially different, that which consists in beginning with causes and tracing them downwards, and that which consists in beginning with effects and tracing them upward; the result is a difference in the very elementary ideas contained in some of the terms used.

But, says Mr. Cotes, p. 52.

> "The sum of the reasoning is briefly this: the number of the comets is very great; their motions are perfectly regular, and observe the same laws as the motions of the planets. They move in conic sections, which are very eccentric. They are carried in all directions towards all parts of the heavens; they pass freely through the planetary regions, and often move contrary to the order of the signs. These phenomena are most evidently confirmed by astronomical observations; and cannot be accounted for by vortices. Nay, they are absolutely inconsistent with the vortices of the planets. For the motions of the comets cannot be performed, if that fictitious matter is supposed to exist in the celestial regions."

According to the present state of science, this is simply untrue, as will be seen in the sequel.

Mr. Cotes again observes, p. 52.

"For, if the planets are carried round the sun by vortices, the parts of the vortices, which immediately surround each planet, are of the same density as the planet; as was shewn above. Therefore all the matter, which is contiguous to the perimeter of the great orb of the earth, must have the same density as the earth. But that which lies between the great orb and the orb of Saturn must either have an equal, or a greater density. For, that the constitution of the vortex may be permanent, the parts of less density ought to occupy the centre, those of greater density to recede further from it. For, since the periodical times of the planets are in the sesquiplicate ratio of their distances from the sun, the periods of the parts of the vortex ought to observe the same proportion. But thence it follows, that the centrifugal forces of these parts are reciprocally as the squares of the distances. Those parts therefore, which are more remote from the centre, endeavour to recede from it with less force: and, if they are less dense, they must yield to the greater force, with which the parts nearer the centre endeavour to ascend. Consequently the denser parts will ascend, and the rarer parts will descend; and there will be a mutual change of places; till the fluid matter of the whole vortex shall be so disposed and adjusted, that being reduced to an equilibrium, it may continue at rest. If two fluids of different density are contained in the same vessel; the fluid, whose density is greater, will by its greater gravity descend to the bottom: and, for a similar reason, the denser parts of the vortex will, by their greater centrifugal force, ascend to the highest parts. Therefore all that by far the greatest part of the vortex, which is without the orbit of the earth, will have a density and an inertness in proportion to the bulk of matter; which will not be less than the density and inertness of the earth: and thence a great and very sensible resistance will arise to the passage of the comets; or rather such as may seem sufficient entirely to absorb and put a stop to their motions. But it appears from the very regular motion of the comets, that they suffer no sensible resistance; and therefore that they never meet with any matter, whose resisting force, and consequently whose density and inertness, is sensible."

The contrary of this is at present maintained, as will be seen in the sequel in regard to the motion of comets. Besides according to the theory of Swedenborg, the denser the parts of the vortex, the nearer are they to the centre, and the more active is the vortex; for every part or particle is a force either in act or in conatus, and the more particles there are the more forces there are, and the stronger is the action of the spiral curve in consequence of its curvature being greater near the sun than at a distance from it. Hence the reader may see the inapplicability to the theory of Swedenborg of the foregoing objections, however justly they may apply to other theories. Thus p. 53, Mr. Cotes continues:

"Bodies moving forward continually communicate part of their own motion to the ambient fluid; and by that communication gradually lose their motion, and are retarded. The retardation is proportional to the motion communicated: but the motion communicated, when the velocity of the moving body is given, is as the density of the fluid: therefore the retardation or resistance will be as the same density of the fluid: nor can it be destroyed in any manner, unless the motion lost is restored by the fluid moving round to the parts behind the body. But this cannot be affirmed, unless the impression of the fluid upon the body behind shall be equal to the impression of the body upon the fluid before; that is, unless the relative velocity, with which the fluid strikes upon the body behind, shall be equal to the velocity with which the body strikes upon the fluid; that is, unless the absolute velocity of the returning fluid shall be twice as great as the absolute velocity of the fluid propelled; which is impossible. Therefore the resistance of fluids, arising from their density and inertness, cannot by any means be taken away. And we must conclude, that the celestial fluid has no inertness, because it has no resisting force: that it has no force by which motion may be communicated, because it has no inertness: that it has no force to produce any change in one or more bodies, because it has no force by which motion may be communicated: that it has no manner of efficacy, because it has no faculty to produce any change.* Therefore this hypothesis, which is plainly without foundation, and which does not in the least help to explain the nature of things, may be justly called ridiculous, and unworthy of a philosopher. Those who are of opinion that the celestial spaces are filled with a fluid matter, and also maintain that it is not inert, deny a vacuum in words, but allow it in fact. For since a fluid matter of this sort cannot be distinguished from empty space;† the whole dispute is about the names, not the natures of things. But if any are so very fond of matter, that they will by no means admit of a space void of body; let us consider what will be the consequence."

---

* The only idea of force which this author seems to have is that of *impulse;* the very existence of which as a celestial force is declared by its opponents to be an assumption;—to say nothing of other objections.

† The author has not shewn this; it is only an assumption.

Mr. Cotes here intimates that fluid matter which fills space, and which is not inert but active, constitutes a vacuum or an empty space; which is so curious an argument, that probably few opponents of vortices would venture to risk it, and hence it does not require any refutation.

Hitherto the alleged errors and inconsistencies of vortical theories have been adduced; from this point the argument changes, and the errors and inconsistencies of the opposite theory are exposed.

First we refer to the alleged inconsistencies.

The author of the *Essay on the First Principles of Natural Philosophy*, (the late Rev. W. Jones of Nayland), observes p. 8:

> "Every person, who makes use of his senses, must needs be convinced, that the matter comprehended within this visible world is full of motion; and the learned have very greatly doubted, by what means, and after what manner, this motion is supported and preserved. Some of them, according to their own accounts, begin with the two principles of *matter* and a *void space*. To their matter they give this capital *law*, that if once moved, it shall continue in motion, because it has no power to *stop itself*. Thus they elude the necessity of providing any *physical* cause for the conservation of motion, and save themselves all that trouble, which they might otherwise have in searching after it. Then, from the principle of a *vacuum*, or space void of all sensible matter, they propose the two following advantages; that a body will have *room* wherein to move, and that being once set a going, there will be nothing in the way to obstruct or diminish the quantity of its motion.
>
> "In this manner they account for the continuance of that motion which is rectilinear: but then for the producing of other motion in curves and compounded directions, with which nature is observed very much to abound, they suppose an emission of immaterial virtues or forces, propagated through their *vacuum* from one parcel of matter to another far distant from it. These virtues are of two sorts: by the one of them, one body is so affected by another as to be *drawn nearer* to it; by the other, it is caused to recede from it: and necessity requires, upon some occasions, that the same parcel of matter be allowed, and that in all its component parts, to have both these powers, though contrary to, and destructive of one another. The names by

which they have been distinguished in different ages are εχθρα and φιλια *love* and *hatred, sympathy* and *antipathy;* and now they pass current under the fashionable terms of *attraction* and *repulsion.* But I presume if we were to call them *a pulling* without any hold, and *a pushing without touching,* we should describe all the sense they have, as well as distinguish one from the other. How or when these qualities came into the world, and *what* they really are, this sort of philosophy thinks itself not concerned to declare; but only to affirm that there *are* such; and, if pressed either with difficulties or absurdities, has this to offer in its defence, that the world is over-ruled by a supreme intelligence, which can act in *any manner,* and which appears from some observations to act in *this* manner.

"These are some of the outlines of the cosmographical system, which was taken up, and cultivated with all the geometrical skill of the great Sir Isaac Newton; who, as an honourable author has truly observed of him, 'was made by nature and inclination for mathematical studies.' Most of our celebrated mathematicians, who are led by a natural bent to a like method of reasoning, are confident, that he has transfused into physical subjects the certainty of geometrical demonstration. Hence they tell us, he *has secured his philosophy from the hazard of being disproved;* and have accordingly bespoken all the *discoveries* that shall happen to arise in *future ages,* which, it seems, are to *confirm and enlarge his doctrines, but can never refute them.* Whether the case does in all points come up to their description of it, we shall be better able to judge, I hope, from the contents of the following sheets.

"Other philosophers there are, who believe the frame of nature to be a perfect and well-ordered machine: in other words, that the visible system of the world, created, disposed, and set into motion by the finger of God, acts as a machine does; a connection and communication being preserved between all the distant parts of it; for, if you interrupt the contact of a machine, you destroy its motion in all those parts from which the communication is cut off. More particularly they assert, that the fluid ethereal matter of the heavens acts by impulse on the solid matter of the earth; is instrumental in every one of its productions; and necessary to all the stated *phenomena* of nature. Hence they divide the elements into *active* and *passive;* not that they are such by any *inherent* or *essential* difference, but that, according to the order established by the divine architect, they are observed to subsist under these different relations."

In the same work the author observes, p. 110:

"We have yet a third question to settle, *viz.* whether *attraction* be a *material* force, or an *immaterial* one? and here we shall have the same scene as before; this point being left equally undetermined with the former. Indeed nothing can be more evident, than that Sir Isaac Newton, great as he was, hath offered to the world his thoughts on a question of much importance, and taken *both sides* of it. It is disagreeable to me to say this; but it must be said, because it is certainly true; and I cannot go forward without saying it. This, as we shall find, has divided his followers; and their disputes with each other in regard to first principles and fundamentals, have as great an appearance of fallibility and uncertainty, as other disputes used to have, before the science of natural philosophy was enriched with demonstration."

Again, p. 123:

"I proposed it as a question, whether attraction be a *material* force or an *immaterial* one? and we have now consulted those writers who ought to have settled the point for us. If Sir Isaac hath really *established* anything on either side, in regard to physical causes, it is astonishing his followers have not fixed upon it, and recommended it to the public with one consent; especially if there be anything of importance depending upon it. But if, on the other hand, the sentiments of their master have given occasion to these disputes, and his writings have furnished them with arguments on both sides; then he himself is chargeable with some inconsistency; and a general agreement among them, in such a case, would be as much to be wondered at. That this latter is the true cause of all their disagreement, will be evident to any reader, who is not so far influenced by the current authority, as to be deterred from making use of his own reason. For if you learn from one page, that it is part of the business of a philosopher *to unfold the mechanism of the world;* and that an *etherial medium* may *suffice* to *impel* bodies; in another it is hinted to you, that the small particles of bodies may have certain *powers* by which they *act at a distance—by attractions.* If you are informed in one place, that when the rays of light are reflected from the *second surface* of a glass laid upon an *exhausted receiver,* this *total reflection* ought to proceed from the *vigour* and *density* of the *medium beyond the glass:* only observe where the same experiment is mentioned in another place, and you will find, the light is now *drawn* back, and that by the *power of the glass,* there being *nothing else to turn it back;* though a while ago there was a *medium* to perform this, endued with *vigour* and *density*. It is suggested, that this *medium* may act upon light so as to *reflect* and *refract* it; and that the *light* in its turn may re-act upon the medium so as to *stir up vibrations* in it: but soon after, it becomes 'inconceivable how two ethers can be diffused through all space, one of which acts upon the other, and by consequence is re-acted upon, without retarding, shattering, dispersing, and confounding one another's motions.'

"I could multiply instances of this sort, wherein the celebrated author has pulled down with one hand, what he had built up with the other: but if men will dare to use their own reason, as I said before, they may easily observe these things for themselves.

"If we go from Sir Isaac to his followers, there the confusion will be still more manifest. Drs. Clarke, Derham, Keil, Friend, Desaguliers, Mr. Cotes, Mr. Rowning, &c., instruct us, that *matter* has *powers, forces, principles, affections, properties, impressed* upon it, *superadded* to it, or *inherent* in it; and that God, when he created the world, *inspirited the materials of it with an active quality.* This was the original doctrine of the mathematic philosophy, and the sense in which it was first embraced by the learned. As it gave birth to many ill-favoured reflections, it is now almost out of fashion; and Mr. Maclaurin rises up to vindicate Sir Isaac, by a substitution of his subtile *ether,* as the mechanical and immediate cause of all that had been falsely imputed to *attraction* by *unskilful* men. This stirs up the indignation of another; who, out of the highest regard to the *memory* of Sir Isaac, pulls this vindication of him all to pieces, represents it as worse than none at all, rejects all *subtile matter* in the lump, and recommends the *immediate influence of the Deity,* as the grand discovery, and the only cure for all disputes. But, for his pains, he is instructed, in his turn, that his own labours have only *served to open up the fallacy of his scheme, and reduce the whole to an absurdity.* There have been heavy complaints, that the philosophy of Sir Isaac hath been *depreciated* and *even ridiculed.* And is it not enough to discompose the muscles of an hermit, to see men thus notoriously contradicting one another, and all gravely pretending to *authority* and *demonstration!* They tell us, there has been a great *discovery* of late years in natural philosophy; it having been found at length, after the world had been in ignorance for many ages, that all matter is endued with *attraction.* If you ask them what they mean by it; it is—an innate virtue or affection of matter; while others affirm, matter can have no such affections. It is the most simple of *causes,* and an *effect,* the cause of which is unknown; it is owing to the agency of a *subtile medium;* and it is effected by the *immediate influence of the Deity:* and if you do not believe this principle, and make use of it to *explain* everything, you are out of the fashion, and what you have to say will be very coldly regarded."

The same author observes, p. 112:

"Mr. Rowning, who has laid down the received philosophy with as much diligence and fidelity as any man, hath affirmed nothing so expressly, as that 'these *dispositions* in bodies (such he calls gravitation, attraction, &c.) are not the result of any mechanical cause whatever, that is, such as may arise from the action of any material substance.' And he has treated his mathematical readers with a demonstration, proving the impossibility of it. Professor S. Gravesande, from whose great abilities we might have expected something more satisfactory, unhappily fell into the same way of reasoning; and gave a geometrical demonstration, (as he thought,) that the spherical figure of a drop of water cannot be occasioned by the *equal pressure* of any fluid medium. More authorities to the same purpose might easily be produced; but this doctrine hath been so largely and confidently maintained by so many writers, that I must have the assent of the learned, if I set it down as a doctrine of Sir Isaac Newton.

"But then, on the contrary, it is to be remembered, that this introducing of immaterial impulses into the world of matter, first raised a clamour against his philosophy, as tending to revive all those occult qualities, which had been so happily banished, but a while before, from all books of natural philosophy. To obviate this, and to *shew*, as the author expresses himself, 'that he did not take gravity for an essential property of bodies,' *he added a question concerning its cause.* This *cause* he supposes to be a *subtile ethereal medium—readily pervading all bodies—expanded through all the heavens—causing the* gravity *of those great bodies* (the sun, planets, comets, &c.) *towards one another, and of their parts toward their bodies*—and such as *may suffice to* impel *bodies from the denser parts of the medium toward the rarer with all that power which we call gravity.* This, I say, is proposed as a *material cause.* For, is it not a *medium,* capable of *rarity* and *density,* subject to a kind of *vibrations* or pulses? and an *immaterial medium* would be an *ens rationis,* a philosophical spectre, a contradiction in terms.

"Here, then, we have two different systems of philosophy. According to the former of them, all the operations of nature are conducted by the means of *unmechanical* and *immaterial impulses* in a *vacuum;* but, according to the latter, they have as their immediate *cause,* an *ether* expanded through all the heavens: and he that shall take up either with the one or the other, or with the one against the other, will have Sir Isaac Newton on his side; but whoever shall assume them *both* as true, will bring himself into great distress and difficulty.

"This was the fate of the ingenious Mr. Maclaurin, a learned and elegant writer, who undertook a formal defence of the Newtonian hypothesis against all the objections that had been made to it; and was well qualified, if any man could be so, for the undertaking. He understood his subject perfectly; and was sensible he could never do justice to the *Principia,* without banishing all material causes from the heavens. This he attempts to do, though it is frequently with some reserve, in several parts of his treatise, particularly in the following words: 'as for a more subtile medium than the air, no experiments nor observations shew, that there is any here, or in the celestial spaces, from which any sensible *resistance* can arise.' Mr. Maclaurin was very well inclined to admit a material agency in subordination to the first cause; but this false doctrine of *resistance* tied up his hands, otherwise his work might have been all of a piece. As it stands now, the most valuable passages in it are so many contradictions to all the rest. After what he has said above, who would expect to hear him reflect upon 'others, who, while they overlook the intermediate *links* in the *chain of causes,* and hastily resolve every principle into the *immediate influence* of the first cause, impair the beauty of nature, put an end to our inquiries into the *most sublime parts of philosophy,* and hurt those very interests they would promote.' They do so most undoubtedly: but hath not the mathematical philosophy this tendency? doth it not oblige us to deny, against reason and our better knowledge, that *any experiments or observations shew that there is a medium more subtile than air?* hath not Mr. Maclaurin himself denied it in these very words? And elsewhere, in the most categorical terms, he hath asserted an absolute *vacuum:*— 'Sir Isaac Newton's philosophy,' says he, 'has shewn, that not only there may be, but that there *actually is a vacuum*—that matter appears to occupy but *a very small portion* of space.' If this should be true, what becomes of his *chain of causes?* for, if there be no medium concerned as a secondary cause in the motion of the planets, &c., it follows unavoidably, that there must either be inherent and self-moving *powers in matter,* or that the influence of the first cause must be *immediate,* for there is nothing else remaining; and then Mr. Maclaurin's chain will consist but of one link. This is the opinion which, he thinks, must *put an end to our enquiries into the most sublime parts of philosophy.* And lest it should be suspected that Sir Isaac's method of philosophizing has introduced *immaterial powers* and occult qualities, we are assured by this author, 'that he does never affirm or insinuate that a body can *act upon another at a distance,* but by the intervention of other bodies.' But his zeal hath carried him a little beyond the truth; the thing he here denies, being much more than *insinuated* in these words: 'Have not the small particles of bodies certain *powers,* virtues, or forces, by which they *act at a distance,* not only upon the rays of light—but also upon one another, for producing a great part of the phenomena of nature? for it is well known that bodies *act upon one another* by the *attractions* of gravity.' &c.

"Attraction, as a power acting *at a distance,* is here left in full possession; not a syllable being inserted, as I can find, concerning the *intervention of other bodies.* If this intervention were admitted, how would it agree with what Dr. Clarke has so frequently inculcated throughout his notes on Rohault's physics: he sticks not to assert an *impulsus non utique corporeus,* and an *actio causæ cujusdam immaterialis —per interjectum aliquod intervallum,* &c., see p. 50. Besides, the sense of the whole passage would be overthrown by Mr. Maclaurin's supposition; for, if other bodies intervene, then attraction will not be a power acting *at a distance,* but by a *communication* of bodies that are in contact. The author (Sir Isaac Newton) does indeed inform us, a while after, that he uses this word to *signify only in general any force,* &c. But this does not alter the case; for, let it be a force *in general,* yet it hath this *particularity* in it, that it *acts at a distance,* which is the nature of an *occult quality,* and is the very thing that has all along been objected to. And though Mr. Maclaurin hath taken great pains to get handsomely rid of this unintelligible power, yet is the existence of such a power absolutely necessary upon his own principles. Sir Isaac, he says, hath shewn, that there *actually is a vacuum* and that the *parts of matter are actually divided and separated from each other:* after which it would be strange, indeed, if they were to *act* otherwise than in this state of *division and separation,* that is, *at a distance.* When he supposes other matter to *intervene,* till the action will consist with mechanism, he apologizes for a *vacuum* at the expense of the principle itself; which, by this means, is turned into a *plenum,* whether the author was aware of it or not."

The alleged inconsistencies in the advocates of the Newtonian system seem to have continued down to the present day. Thus for instance, Mr. Whewell observes in his *Treatise on the Free Motion of Points, and on Universal Gravitation.* p. 209:

"That the planets and the earth, in the order in which they are above enumerated, revolve about the sun in orbits nearly circular, is a doctrine established by Copernicus and his successors in philosophy, and capable of being proved by incontrovertible reasonings.

"Attempts have been made to explain the motions of the heavenly bodies by means of material connexions between them and the centres about which they move: such pieces of machinery were sometimes supposed to be transparent and solid, and were then conceived as *crystalline spheres;* or they were asserted to be fluid, and to revolve like a whirl of water or air, and were then called *vortices.* All these attempts were found to be quite inadequate to account for the movements of the stars such as they are observed; and the existence of such a frame-work of the heavens being also utterly unsupported by any evidence of the senses, there is no longer a single tenable argument for it.

"We are left therefore to the remaining supposition, that the heavenly bodies revolve in a space which is empty, or nearly empty of inert matter; and that their movements are regulated, not by material agents with which they are in contact, but by the forces of bodies acting upon them at a distance. They must therefore be governed by the laws of motion established in the previous part of this work; and the propositions already demonstrated concerning the effects of forces will apply to them."

Here we have presented to us *one* version of the Newtonian philosophy, which consists in maintaining the doctrines of a vacuum and of forces acting at a distance, &c. (See also *The Philosophy of the Inductive Sciences,* vol. ii., p. 448).

On the other hand Captain Smyth observes in his *Cycle of Celestial Objects,* vol. i., p. 251.

"It was advanced, that no motion could be more equal, constant, and accordant, than that of the planets round the sun; but a medium which may impress no appreciable opposition to the solid and weighty mass of a planet, may produce a very perceptible difference in the time of the revolution of a gaseous wanderer. Hence Dr. Olbers has said: 'The exemption of the dense and solid bodies of the planets from any sensible effects of resistance, in the interplanetary spaces, proves nothing with respect to comets, which occupying, perhaps, a volume 1000 times as great, may have masses 1000 times smaller.' Newton himself—albeit often brought forward as the advocate of a *vacuum*—supposed that a *spiritus subtilissimus* was diffused through space, diminishing in the inverse ratio of the square of the sun's distance; and if this ether, said he, should be supposed to be 700,000 times more elastic than our air, and above 700,000 times more rare, its resistance would be about 600 billion times less than that of water, a resistance which would scarce make any sensible alteration in the motions of the planets in 10,000 years. 'If any one would ask,' he adds, 'how a medium can be so rare, let him tell me, how an electric body can by friction emit an exhalation so rare and subtile, and yet so potent? And how the effluvia of a magnet can pass through a plate of glass, without resistance, and yet turn a magnetic needle beyond the glass?' The magnitude of the retardation is a quantity too large to be a doubtful case, the supposition, therefore, that the heavens oppose a gaseous ether to the motion of bodies, became necessary to reconcile these anomalies; and it is seen, that this fluid only retards the progress of the comet, without altering its course."

The doctrine of forces acting at a distance, as they are said to do in the case of a vacuum, was denied by the Ontologists as an impossibility (see Wolffe's *Cosmology,* art. 323); and the existence of some contiguous and connecting medium they maintained to be necessary; indeed that some such medium or mode of connection must exist seems to be intimated by Sir William Herschel, as the natural and necessary conclusion of the human mind from analogy, even were there no positive evidence in favor of it. Thus he observes in his *Natural Philosophy* p. 193.

"In like manner we see that the moon circulates about the earth; and because we believe it to be a solid mass, and have never seen one solid substance revolve round another within our reach to handle and examine unless retained by a force or united by a tie, we conclude that there *is* a force, and a mode of connexion, between the moon and the earth; though, what that mode can be, we have no conception, nor can imagine *how* such a force can be exerted at a distance, and with empty space, or at most an invisible fluid, between."

Finally, Mr. Robert Young observes in his *Essay on the Powers and Mechanism of Nature,* p. 207:

"Our habit of conceiving the planets to revolve in spaces almost or altogether void, and as *attracting* each other, at great distance, through this void, may impede the familiar conception of these spheres of activity, as extensions of actual and ACTIVE SUBSTANCE diffused around each planet: but we have, all along, assumed it as evident, that where there is *action,* there is *substantial existence,* and consequently that to whatever apparent distance bodies manifest that power called *attraction,* it is not truly a distant action, but the action of a substance, present where it acts, and consequently extended about the central globe (said to possess the attractive force), to the distance of the body acted upon. The planets, therefore, cannot be said to attract or act upon each other, at a distance, or through void extensions; their spheres of attraction, as they are called, are spheres of an ACTIVE SUBSTANCE, less dense than the planet which occupies the centre of those spheres; and the active sphere of each planet acts not on the *body* of another planet, but on the *active sphere* of that other planet, extended so as to intersect the former. This idea is not dissonant to the opinion of Newton, who expressly rejects the notion of bodies acting at a distance, as being what no philosopher can entertain."

Let us now, however, proceed to some positive evidence in favour of the existence of a subtile medium universally pervading space; an evidence by which a great portion of Mr. Cotes' argument against the doctrine of vortices will be subverted.

Professor Nichols observes in his *Architecture of the Heavens,* p. 154:

"Until recently, astronomical science has not been able to present a complete and minutely accurate view of the orbit of any comet. The general character of the orbits of these bodies, and the important elements, at least of *one* of them, have been known since the time of the celebrated Halley; but this philosopher knew nothing further than the general elements; and no orbit was laid down with exactness sufficient for the above purpose, until Encke of Berlin examined with so much accuracy the conditions of a *body*—if a thing so small and vaporous merits the appellation—which completes its eccentric course around the sun in $3\frac{1}{2}$ years. Now, it appears by observation, that this comet *is approaching the sun*;—on every successive appearance, we find its orbit somewhat contracted, and there is reason to believe that the contraction will go on until it is either absorbed in that luminary, or altogether dissipated by his beams. And after vainly searching for some other cause, inquirers are nearly unanimous in referring this extraordinary and hitherto unparalleled change, to a RESISTING MEDIUM OR ETHER occupying the planetary spaces. 'I cannot but express my belief,' says Professor Airy, 'that the principal part of the theory, viz., an effect exactly similar to that which a resisting medium would produce, is perfectly established by the reasoning in Encke's memoir;' and similar opinions have been offered by other great authorities. That the sun, then, has a widely diffused nebulous atmosphere—extending far beyond the limits of the zodiacal light, and if not beyond, at least deep into the planetary spaces—an atmosphere of which that light may merely be the densest portion, is at length rested on a high degree of probability: and how singular is it that we should have been guided to a truth so remote and difficult—one concerning which the grander phenomena of our system are silent, by the motions of a wandering object, in comparison with whose ethereal nature, even one of these light flocculi or flakes of cloud, which scarce stain the sky of a summer evening, is heavy and substantial! Even thus harmonious is the universe! And seeing the perfect continuity of that golden line of order, which unites its mightiest phenomena with its least, so that the motions of a speck of dust may illustrate causes adequate to generate worlds,—what achievement is too high to be hoped for future discovery, and why may not a time arrive, when, in return for man's close observation, and unwearied questioning of nature, the darkest of those speculations in which we have just been indulging, shall be doubful and venturous no more?

"If consideration of these circumstances has sufficed to destroy your natural repugnance to the resolution of our effulgent sun into a nebula, you will be prepared to start the next question—the question as to the capacity of the hypothesis, that the sun sprung from such a mass, to explain the most remarkable feature of his being, viz. his rotation round an axis."

Captain Smyth observes in his *Cycle of Celestial Objects*, vol. i. p. 251, speaking of Encke's comet:

"Its orbit is an ellipse of comparatively small dimensions, almost in the plane of the ecliptic, and wholly within the march of Jupiter, one extremity reaching a little beyond the orbit of Pallas, and the other extending to that of Mercury.

"Nothing could be more satisfactory that all this; but the period of $3\frac{3}{10}$ years was found to be accelerated about two days in each revolution. The possible derangement which the comet would suffer from planetary influences, had been duly calculated; yet, at each re-appearance there was a difference between the prediction and observation, and always on the same side. This was directly imputed to the resistance of some ethereal fluid, or modification of light and heat, and constituted what Sir John Herschel aptly termed the residual phenomenon. As this seemed to be a revival of Aristotle's fifth element, the *quinta essentia* of after times, and the Leibnitzian doctrine of ether, the question was approached with delicacy; and it is only now, that it may be deemed orthodox to believe in the existence of a resisting medium."

Again, p. 252.

"The return of Halley's comet in 1911, will solve several questions of deep interest connected with the ethereal medium. An opinion prevails, that this fluid has a rotatory motion about the sun from west to east, communicated to it by the incessant gyrations of the planets. Should such a rotation exist, it must have a widely different effect upon Halley's comet, which moves from east to west, from that which it produces upon Encke's and Biela's comets revolving in a contrary direction. These points, comparatively speaking, will soon be settled."

"Thus does this obscure, tail-less object, seem to have revealed the secret of a rare medium filling space, of which the planets give no indication, they performing their evolutions as in a perfect vacuum. Besides this, it is weighing one world and registering the experiment to another, for it will enable us to obtain the mass of Mercury, which is as yet but hypothetically known; and it may yet open other views of importance and grandeur. The constant decrease in the size of its orbit consequent upon the resisting medium, may possibly precipitate it on the surface of the sun, if, before that event takes place, the perpetual diminution of its mass does not either dissipate it or condense it into a solid state. The question is a very singular one."

Mrs. Somerville observes in her *Connexion of the Physical Sciences,* p. 27:

"The existence of an ethereal fluid is now proved; and, although it is so extremely rare that hitherto its effects on the motions of the planets have been altogether insensible, there can be no doubt, that, in the immensity of time, it will modify the forms of the planetary orbits, and may at last even cause the destruction of our system, which in itself contains no principle of decay, unless a rotatory motion from west to east has been given to this fluid by the bodies of the solar system, which have all been revolving about the sun in that direction for unknown ages. This rotation, which seems to be highly probable, may even have been coëval with its creation. Such a vortex would have no effect on bodies moving with it, but it would influence the motions of those revolving in a contrary direction. It is possible that the disturbances experienced by comets which have already revealed the existence of this fluid, may also, in time, disclose its rotatory motion."

Again, p. 39:

"The identity of the velocity of light, at the distance of Jupiter, and on the earth's surface, shows that its velocity is uniform; and if light consists in the vibrations of an elastic fluid or ether filling space, an hypothesis which accords best with observed phenomena, the uniformity of its velocity shows that the density of the fluid throughout the whole extent of the solar system must be proportional to its elasticity."

Again, p. 194, speaking of the analogy between undulations of fluids and certain phenomena of light:

"The analogy is indeed so perfect, that philosophers of the highest authority concur in the supposition that the celestial regions are filled with an extremely rare, imponderable, and highly elastic medium or ether, whose particles are capable of receiving the vibrations communicated to them by self-luminous bodies, and of transmitting them to the optic nerves, so as to produce the sensation of light. The acceleration in the mean motion of Encke's comet, as well as of the comet discovered by M. Biela, renders the existence of such a medium almost certain."

Again, p. 375:

"But an all-pervading ether probably fills the whole visible creation, and conveys in the form of light, tremors which may have been excited in the deepest recesses of the universe thousands of years before we were called into being. The existence of such a medium, though at first hypothetical, is nearly proved by the undulatory theory of light, and rendered all but certain within a few years by the motion of comets, and by its action upon the vapours of which they are chiefly composed. It has often been imagined, that, in addition to the effects of heat and electricity, the tails of comets have infused new substances into our atmosphere."

Again, p. 384:

"Among the many perturbations to which the planets are liable, their mean motions, and therefore the major axes of their orbits experience no change; while on the contrary, the mean motion of the moon is accelerated from age to age, a circumstance at first attributed to the resistance of an ethereal medium pervading space, but subsequently proved to arise from the secular diminution of the eccentricity of the terrestrial orbit. Although the resistance of such a medium has not hitherto been perceived in the motions of such dense bodies as the planets and satellites, its effects on the revolutions of the two small periodic comets hardly leave a doubt of its existence. From the numerous observations that have been made on each return of the comet of the short period, the elements have been computed with great accuracy on the hypothesis of its moving in vacuo. Its pertubations occasioned by the disturbing action of the planets have been determined; and after everything that could influence its motion had been duly considered, M. Encke found that an acceleration of about two days in each revolution has taken place in its mean motion, precisely similar to that which would be occasioned by the resistance of an ethereal medium. And as it cannot be attributed to a cause like that which produces the acceleration of the moon, it must be concluded that the celestial bodies do not perform their revolutions in an absolute void, and that although the medium be too rare to have a sensible effect on the masses of the planets and satellites, it nevertheless has a considerable influence on so rare a body as a comet. Contradictory as it may seem, that the motion of a body should be accelerated by the resistance of an ethereal medium, the truth becomes evident if it be considered that both planets and comets are retained in their orbits by two forces which exactly balance one another; namely, the centrifugal force producing the velocity in the tangent, and the attraction of the gravitating force directed to the centre of the sun. If one of these forces be diminished by any cause, the other will be proportionally increased. Now, the necessary effect of a resisting medium is to diminish the tangential velocity, so that the balance is destroyed, gravity preponderates, the body descends towards the sun till equilibrium is again restored between the two forces; and as it then describes a smaller orbit, it moves with increased velocity. Thus, the resistance of an ethereal medium actually accelerates the motion of a body; but as the resisting force is confined to the plane of the orbit, it has no influence whatever on the inclination of the orbit, or on the place of the nodes. In computing its effect, M. Encke assumed the increase to be inversely as the squares of the distances, and that its resistance acts as a tangential force proportional to the square of the comet's actual velocity in each point of its orbit. The other comet belonging to our system, which returns to its perihelion after a period of 6¾ years, has been accelerated in its motion by a whole day during its last revolution, which puts the existence of ether nearly beyond a doubt, and forms a strong presumption in corroboration of the undulatory theory of light. Since this comet which revolves nearly between the orbits of the earth and Jupiter, is only accelerated one day at each revolution, while Encke's, revolving nearly between the orbits of Mercury and Pallas, is accelerated two, the ethereal medium must increase in density towards the sun."*

Again, p. 424:

"The astonishing multitudes of shooting stars and fire balls that have appeared within these few years at stated periods over the American continent, and other parts of the globe, warrant the conclusion that there is either a nebula, or that there are myriads of bodies revolving in groups round the sun which only become visible when inflamed by entering our atmosphere."

Lastly Professor Nichols has observed in his *Architecture of the Heavens,* p. 157:

"When we reflect on the solar or any other nebula in the act of condensing, it appears that the phenomenon consists in a flow or rush of the nebulous matter from all sides towards a central region; which is virtually equivalent, in a mechanical point of view, to what we witness so frequently, both on a small and large scale—the meeting and intermingling of opposite gentle currents of water. Now what do we find on occasion of such a meeting? Herschel's keen glance lighted at once on this simple phenomenon, and drew from it the secret of one of the most fertile processes of Nature! In almost no case do streams meet and intermingle, without occasioning where they intermingle, a *dimple* or WHIRLPOOL [*vortex*]; and, in fact, it is barely possible that such a flow of matter from opposite sides could be so nicely balanced in any case, that the opposite momenta or floods would neutralize each other, and produce a condition of *central rest*. In this circumstance then—in the whirlpool [*vortex*] to be expected where the Nebulous floods meet—is the obscure and simple germ of rotatory movement. The very act of the condensation of the gaseous matter as it flows towards a central district, almost necessitates the commencement of a process, which, though slow and vague at first, has, it will be found, the inherent power of reaching a perfect and definite condition, and from which consequences ultimately issue, not less various and astonishing than the foliage and stature of the noble tree, considered as the development of an insignificant seed.

---

* See also Whewell's Bridgewater Treatise, chap. xvii., p. 138.

"You will have no difficulty in perceiving, that—the whirlpool [*vortical*] motion once originated—there is an inherent power in matter, under such circumstances, to evolve finally a definite rotation of considerable velocity."

Upon a review of these several quotations, we observe a remarkable confirmation of the general principles of the theory maintained in the first part of Swedenborg's *Principia;* for the foregoing nebular hypothesis, as we shall perceive in the sequel, is not at all necessarily restricted to those nebulæ which were wrongly supposed to be irresolvable; and if, notwithstanding what has been said, the reader should find himself embarrassed by any theory of vortices in consequence of the heterogeneous motions of comets, let him remember Sir William Herschel's remark in his *Discourse on the Study of Natural Philosophy,* p. 195:

"Now, nothing is more common in physics than to find two, or even many, *theories* maintained as to the origin of a natural phenomenon. For instance, in the case of heat itself, one considers it as a really existing material fluid, of such exceeding subtlety as to penetrate all bodies, and even to be capable of combining with them chemically;

while another regards it as nothing but a rapid vibratory or rotatory motion in the ultimate particles of the bodies heated; and produces a singularly ingenious train of mechanical reasoning to show, that there is nothing contradictory to sound dynamical principles in such a doctrine. Thus, again, with light: one considers it as consisting in actual particles darted forth from luminous bodies, and acted upon in their progress by forces of extreme intensity residing in the substances on which they strike; another, in the vibratory motion of the particles of luminous bodies, communicated to a peculiar subtile and highly elastic ethereal medium, filling all space, and conveyed through it into our eyes, as sounds are to our ears, by the undulations of the air.

"Now, are we to be deterred from framing hypotheses and constructing theories, because we meet with such dilemmas, and find ourselves frequently beyond our depth? Undoubtedly not. *Est quoddam prodire tenus si non datur ultra.* Hypotheses, with respect to theories, are what presumed proximate causes are with respect to particular inductions: they afford us motives for searching into analogies; grounds of citation to bring before us all the cases which seem to bear upon them, for examination. A well imagined hypothesis, if it have been suggested by a fair inductive consideration of general laws, can hardly fail at least of enabling us to generalize a step farther, and group together several such laws under a more universal expression. But this is taking a very limited view of the value and importance of hypotheses: it may happen (and it has happened in the case of the undulatory doctrine of light) that such a weight of analogy and probability may become accumulated on the side of an hypothesis, that we are compelled to admit one of two things: either that it is an actual statement of what really passes in nature, or that the reality, whatever it be, must run so close a parallel with it, as to admit of some mode of expression common to both, at least in so far as the phenomena actually known are concerned. Now, this is a very great step, not only for its own sake, as leading us to a high point in philosophical speculation, but for its applications; because whatever conclusions we deduce from an hypothesis so supported must have at least a strong presumption in their favour: and we may be thus led to the trial of many curious experiments, and to the imagining of many useful and important contrivances, which we should never otherwise have thought of, and which, at all events, *if* verified in practice, are real additions to our stock of knowledge and to the arts of life.

"In framing a theory which shall render a rational account of any natural phenomenon, we have *first* to consider the agents on which it depends, or the causes to which we regard it as ultimately referable.

These agents are not to be arbitrarily assumed; they must be such as we have good inductive grounds to believe do exist in nature, and do perform a part in phenomena analogous to those we would render an account of; or such, whose presence in the actual case can be demonstrated by unequivocal signs. They must be *veræ causæ,* in short, which we cannot only show to exist and to act, but the laws of whose action we can derive independently, by direct induction, from experiments purposely instituted; or at least make such suppositions respecting them as shall not be contrary to our experience, and which will remain to be verified by the coincidence of the conclusions we shall deduce from them, with facts."

We now proceed to the Second Part of the *Principia,* in which it is the object of Swedenborg to illustrate and confirm the theory of vortices by the phenomena of the magnet, and again the phenomena of the magnet by the theory of vortices; premising, that it is not our intention to enter into the subject of Mr. Faraday's discoveries, since on the one hand they are obviously not yet completed, and on the other, the principles of the present work have not yet been sufficiently tested.

Hitherto the author's proofs have been philosophical and geometrical; he now advances to the physical; that is to say, having explained his hypothesis in the First Part, he proceeds to the *vera causa,* and to shew that forces such as he has hypothetically described as constituting the solar vortex, have an actual existence in our mundane system, and are exhibited to the senses in the phenomena of the magnet. These phenomena are derived from the experiments made by Muschenbroek, and published by him in his *Physicæ Experimentales et Geometricæ de Magnete, &c.* Muschenbroek seems to consider that the magnetical attractions and repulsions observe no certain law, and therefore he assigns none. Swedenborg considers that the reason of this conclusion is to be found in the difficulty of obtaining a purely magnetic substance; which, if once obtained and secured from foreign influences, would be found to exhibit a uniform law of attraction and repulsion. This law has since been discovered by Mr. Michell in 1750, and has been ascertained to be the same with that of gravitation, or to coincide with the squares of the distances inversely. Thus in Sir David Brewster's *Treatise on Magnetism,* it is observed, p. 15:

"There have been," says Mr. Michell, "some who have imagined that the decrease of the magnetic attraction and repulsion is inversely as the cubes of the distances; others as the squares; and others, that it follows no certain ratio at all, but that it is much quicker at great distances than at small ones, and that it is different in different stones. Among the last is Dr. Brooke Taylor and Muschenbroek, who seem to have been pretty accurate in their experiments. The conclusions of these gentlemen were drawn from their experiments, without their being aware of the third property of magnets just mentioned, which, if they had made proper allowances for, together with the increase and diminution of power in the magnets they tried their experiments with, all the irregularities they complained of (as far as appears from their relations of them) might very well be accounted for, *and the whole of their experiments coincide* with the squares of the distances inversely."

The experiments of Muschenbroek then are allowed to be accurate, and may be made to harmonize with the law of gravitation. But as Swedenborg regards both gravity and magnetism as having the same original, so there seems to be nothing in the *Principia* to dissent from the now established law of magnetism, according to which the intensity of the force is inversely as the square of the distance. Moreover since according to the theory of Swedenborg, heat, light, magnetism, and electricity, are only different modifications of one common force; so the theory harmonizes with the following generalization mentioned by Dr. Roget in his observations on magnetism, p. 16, where he says:

"It has been ascertained most satisfactorily that the same law of variation obtains in magnetic attractions and repulsions with relation to proximity, as in the electrical: namely, that the intensity of the force by which magnetic polarities act upon each other is inversely as the square of their distance. In this respect therefore, they agree, not only with the electrical forces, but also with that of gravitation; and it would appear, indeed, to be a property common to all forces which emanate in every direction from a central agent."

To say nothing of the theory of Des Cartes which was adopted by Euler and Bernoulli, or of the various eminent theorists and experimentalists, who from time to time have advanced the science of magnetism to its present condition, we will merely observe that among the theories which in modern times have attracted most notice are those of Œrsted and Ampère, an account of which may be seen in Dr. Roget's *Treatise on Electro-Magnetism* and other works. It would seem indeed as if almost every theory would explain more or less certain magnetic phenomena, but that of Ampère is said to explain the greater number; while on the other hand every theory is said to have its difficulties; nor does there seem to be one which is not daily undergoing some change or modification, or else altogether shifting its grounds in consequence of new discoveries. Ampère, it appears, explains magnetism by electricity; on the other hand Swedenborg explains electricity by magnetism.* But if the theory of Ampère is in this respect opposed to that of Swedenborg, in other respects it presents a certain resemblance. For instance, in explaining the action of a cylindrical magnet, he supposes the existence of a number of similar helices or spirals, parallel to each other and moving round axes. Thus Dr. Roget observes, p. 83:

> "It is obvious that in order to institute an exact comparison between the action of a magnet, and that of an artificial assemblage of electric currents similar to that which is supposed by the theory to exist in the magnet, our imitation must be made by collecting together a great number of similar helices, in parallel directions, and uniting them in one mass. Such an arrangement is called by Ampère *an Electro-dynamic Solenoid*."

To proceed farther into this subject would at present be only to embarrass the reader with conflicting theories. For example, in the investigation of terrestrial magnetism, Professor Gauss maintains that the only foundation of any true theory is the *datum* that the earth is a true magnet.† Sir David Brewster, on the other hand, considers such a principle to be fallacious.‡ Halley considered there were four magnetic poles to the earth; more recently this hypothesis has been adopted by Professor Hansteen; while on the other hand Professor Gauss§ considers that there are only two; to say nothing of other conflicting statements. To compare then a formal and settled theory, whether true or false, like that of Swedenborg with theories, which in the present state of science are ever varying, would only be an unprofitable task. We shall however furnish a few extracts from modern writers which may be useful to the reader, on the subject of terrestrial magnetic lines, and upon errors of observation.

---

* The Translator does not recollect that Swedenborg in any part of his works indicates a knowledge of the magnetic curve.

† See Taylor's *Scientific Memoirs*, August, 1839, p. 185.

‡ See Brewster's *Treatise on Magnetism*, p. 263.

§ See Taylor's *Scientific Memoirs*, August, 1839, pp. 195, 223.

With regard then to the former, Dr. Thomson observes in his *Outlines of the Science of Heat and Electricity*, p. 552:

> "As the magnetic poles do not coincide with the terrestrial poles, it is obvious that the magnetic equator cannot coincide with the terrestrial equator. From the numerous observations made in different parts of the torrid zone, there is reason to conclude that the magnetic equator is distant at a maximum about 12° from the earth's equator. It would appear to be a great circle of the sphere cutting the earth's equator, in west longitude about 113,° or a little to the west of Gallego in the Pacific Ocean, and in east longitude 67° in the Indian Ocean. But in all parts of the Pacific Ocean, to the west of the Gallipago Node, there must exist another magnetic equator, as is obvious from the observations of Cooke, Bailey, and various other observers. It must cut the equator once, if not twice, between Gallipago and the Chinese Sea. Indeed, the existence of four terrestrial poles ought to give origin to different magnetic equators, in different parts of the globe. For a magnetic equator is merely a place where the north and south poles of a magnet are equally acted upon by the terrestrial poles. The nodes of the magnetic equator must of course shift their positions, as the magnetic poles of the earth by acting upon each other alter their direction. Probably they will be found to revolve slowly round the earth's equator."

The reader will find in the treatise of Sir David Brewster, p. 233, a further and more ample description of the magnetic equator; we shall only extract the following, p. 238:

> "From these facts it appears, *that the magnetic equator will meet the equinoctial line only in two points, which are diametrically opposite, the one situated in the Atlantic Ocean, and the other in the great ocean nearly in the plane of the meridian of Paris. When this equator meets only some scattered islands, it recedes only a little from the equinoctial line. When the islands are more numerous, it recedes farther; and it reaches its maximum deviation in both hemispheres only in the two great continents which it traverses. He found also, that between the northern and southern halves of the magnetic equator, there is a sym-*

metry very remarkable, and much more perfect than had been previously believed."

Closely connected with this subject is Professor Gauss' remark on the three systems of magnetic lines. Thus in Taylor's *Scientific Memoirs,* August, 1839, p. 184, it is observed :

"It has been customary to represent the results of magnetic observations by three systems of lines, usually termed Isogonic, Isoclinal, and Isodynamic lines. In course of time these lines undergo considerable alterations both in position and in figure, so that a drawing of them represents the phenomena correctly only for the epoch to which it corresponds. Halley's Chart of Declination for 1700 is very different from that of Barlow for 1833 ; and already Hansteen's Dip Chart for 1780 differs greatly from the present position of the Isoclinal lines. Doubtless, in course of time, similar alterations in the lines of intensity will be manifested ; but observations of this nature are altogether too recent to furnish such indications at present.

"In all these maps there exist spaces either blank, or in which the lines are but indifferently supported by observation. The inaccessibility of parts of the earth's surface renders perfection in this respect impossible ; but a rapid progress towards it may be confidently hoped for.

"Viewed from the higher grounds of science even a complete representation of the phenomena after this manner is not itself the final object sought. It is rather analogous to what the astronomer has accomplished, when, for example, he has observed the apparent path of a comet in the heavens. Until the complicated phenomena have been brought in subjection to a common principle, we have only building-stones, not an edifice.

"The astronomer, after the comet has disappeared from his view, begins his chief employment, and resting on the laws of gravitation, calculates from the observations the elements of its true path, and is thus enabled to predict its future course. And in like manner the magnetician proposes to himself as the object of his research, as far as the different and in some respects less favourable circumstances permit, —the study of the fundamental causes which produce the phenomena, their magnitude and their mode of operation,—the subjection of the observations, as far as they extend, to those elementary principles,— and the anticipation, with some approximation at least, of their effects, in those regions where observation has not yet penetrated. It is at least well to keep in view this higher object, and to endeavour to prepare the way for it, even though the great imperfection of the data may render its attainment impossible at present."

On the subject of errors of observation it is remarked in the same article, p. 222:

"In judging of the differences between calculation and observation, as shown in the foregoing tabular comparison, it must be remembered, on the one hand, that almost all the observations are charged both with the errors of observation, and with the influence of the accidental anomalies of the magnetic force itself, and that they do not correspond to the same year." . . &c.

Again in a note it is observed:

"The last article presents instances of discordances between different observers at one and the same place; I will notice some others, which are much greater than can with any degree of probability be attributed to yearly changes. The dip at Valparaiso was, in 1829, according to King, 40° 11′; in 1835, according to Fitz Roy, 38° 3′. In Mauritius the intensity was 1·096 in 1818, according to Freycinet, and 1·192 in 1836, according to Fitz Roy. The difference is still greater at Otaheite, where Erman's intensity = 1·172 in 1830, and Fitz Roy's, in 1835, = 1·017. Otaheite is a station of the highest importance for the future improvement of the elements: the difference between the two determinations made there by different observers, considerably exceeds the greatest difference between the computed and observed intensities in our eighty-six comparisons."

These remarks then upon the subjects treated of in the second part of the *Principia* may be concluded with the following observation. Whether the theory of magnetism propounded by Swedenborg, be true or not; or how far it may be susceptible of modifications which may make it true, the translator feels it would be presumption in him to hazard an opinion. Like all other theories, it must be tried by ascertained facts, and in thus presenting it to the reader in an English version, the translator has only attempted to bring a work, almost universally unknown, within the notice of those scientific enquirers who are devoted to these subjects; and who have admitted that a true theory of magnetism is still a *desideratum*.

We now come to the consideration of the third part of the *Principia*, which is devoted principally to a theory of Cosmogony in accordance with the laws of the mechanism of the elements and vortices, propounded in Part the First.

In treating of this subject, we shall pursue the same plan as in regard to elements and vortices, and compare the cosmogonical theory of Swedenborg with those of other authors, so that we may be able to form some idea of the comparative merits of Swedenborg's theory, and of its true place in the modern history of cogmogonical theories.

In Whewell's Bridgewater Treatise on *Astronomy and General Physics,* it is observed, p. 172, in respect of Sir Isaac Newton:

"In his first letter to Bentley, he allows that matter might form itself into masses by the force of attraction. 'And thus,' says he, 'might the sun and fixed stars be formed, supposing the matter were of a lucid nature. But how the matter should divide itself into two sorts; and that part of it which is fit to compose a shining body should fall down into one mass, and make a sun; and the rest, which is fit to compose an opaque body, should coalesce, not into one great body, like the shining matter, but into many little ones; or if the sun at first were an opaque body like the planets, or the planets lucid bodies like the sun, how he alone should be changed into a shining body, whilst all they continue opaque; or all they be changed into opaque ones, while he continued unchanged: I do not think explicable by mere natural causes, but am forced to ascribe it to the counsel and contrivance of a voluntary Agent."

Such appear to be the first general surmises of Sir Isaac Newton with regard to a theory of cosmogony founded upon the ascertained laws of gravitation. The person who next followed out these surmises was Swedenborg, for he published his *Principia* in 1738, but the nature of the subject requires us for the present to pass on to Buffon.

With regard to this author La Place observes in his *System of the World,** vol. ii., p. 359:

"To investigate the cause of the primitive motions of the planets, we have given the five following phenomena: 1st. The motions of planets in the same direction, and nearly in the same plane. 2nd. The motion of their satellites in the same direction, and nearly in the same plane with those of the planets. 3rd. The motion of rotation of these different bodies, and of the sun in the same direction as their motion of projection, and in planes but little different. 4th. The small eccentricity of the orbits of the planets, and of their satellites. 5th. The great eccentricity of the orbits of comets, although their inclinations may have been left to chance.

---

* Pond's Translation.

"Buffon is the only one whom I have known, who, since the discovery of the true system of the world, has endeavoured to investigate the origin of the planets, and of their satellites. He supposes that a comet, in falling from the sun, may have driven off a torrent of matter, which united itself at a distance, into various globes, greater or smaller, and more or less distant from this luminary. These globes are the planets and satellites, which, by their cooling, are become opaque and solid.

"This hypothesis accounts for the first of the five preceding phenomena; for, it is clear that all bodies thus formed, must move nearly in the plane which passes through the centre of the sun, and in the direction of the torrent of matter which produces them. The four other phenomena appears to me inexplicable by his theory. In fact, the absolute motion of the particles of a planet would then be in the same direction of the motion of its centre of gravity; but it does not follow that the rotation of the planet would be in the same direction. Thus, the earth may turn from west to east, and yet the absolute direction of each of its particles may be from east to west. What I say of the rotatory motion of the planets, is equally applicable to the motion of their satellites in their orbits, of which the direction in the hypothesis he adopts, is not necessarily the same with the projectile motion of the planets.

"The small eccentricity of the motion of the planetary orbits, is not only very difficult to explain on this hypothesis, but the phenomenon contradicts it. We know by the theory of central forces, that if a body moving in an orbit round the sun, touched the surface of this luminary, it would uniformly return to it at the completion of each revolution, from whence it follows, that if the planets had originally been detached from the sun, they would have touched it at every revolution, and their orbits, far from being circular, would be very eccentric. It is true, that a torrent of matter, sent off from the sun, cannot correctly be compared to a globe which touches its surface. The impulse which the particles of this torrent receive from one another, and the reciprocal attraction exercised among them, may change the direction of their motion, and increase their perihelion distances; but their orbits would uniformly become very eccentric, or at least it must be a very extraordinary chance that would give them eccentricities so small as those of the planets. In a word, we do not see, in this hypothesis of Buffon, why the orbits of about eighty comets, already observed, are all very elliptical. This hypothesis, then, is far from accounting for the preceding phenomena. Let us see if it is possible to arrive at their true cause."

Such is the statement of Buffon's theory by La Place, and his refutation of it; after which he proceeds to suggest his own in the following manner, p. 362:

"Whatever be its nature, since it has produced or directed the motion of the planets and their satellites, it must have embraced all these bodies, and considering the prodigious distance which separates them, they can only be a fluid of immense extent. To have given in the same direction, a motion nearly circular round the sun, this fluid must have surrounded the luminary like an atmosphere. This view, therefore, of planetary motion, leads us to think, that in consequence of excessive heat, the atmosphere of the sun originally extended beyond the orbits of all the planets, and that it has gradually contracted itself to its present limits, which may have taken place from causes similar to those which caused the famous star that suddenly appeared in 1572, in the constellation Cassiopæa, to shine with the most brilliant splendour during many months.

"The great eccentricity of the orbits of comets, leads to the same result; it evidently indicates the disappearance of a great number of orbits less eccentric, which indicates an atmosphere round the sun, extending beyond the perihelion of observable comets, and which, in destroying the motion of those which they have traversed in a duration of such extent, have reunited themselves to the sun. Thus, we see that there can at present only exist such comets as were beyond this limit at that period. And as we can observe only those which in their perihelion approach near the sun, their orbits must be very eccentric: but, at the same time, it is evident that their inclinations must present the same inequalities as if the bodies had been sent off at random, since the solar atmosphere has no influence over their motions. Thus, the long period of the revolutions of comets, the great eccentricity of their orbits, and the variety of their inclinations, are very naturally explained by means of this atmosphere.

"But how has it determined the motions of revolution and rotation of the planets? If these bodies had penetrated this fluid, its resistance would have caused them to fall into the sun. We may then conjecture, that they have been formed at the successive bounds of this atmosphere, by the condensation of zones, which it must have abandoned in the plane of its equator, and in becoming cold have condensed themselves towards the surface of this luminary, as we have seen in the preceding book. One may likewise conjecture, that the satellites have been formed in a similar way by the atmosphere of the planets. The five phenomena, explained above, naturally result from this hypothesis, to which the rings of Saturn add an additional degree of probability.

"Whatever may have been the origin of this arrangement of the planetary system, which I offer with that distrust which everything ought to inspire that is not the result of observation or calculation; it is certain that its elements are so arranged, that it must possess the greatest stability, if foreign observations do not disturb it. Through this cause alone, that the motions of planets and satellites are nearly circular, and impelled in the same direction, and in planes differing but little from each other, it arises that this system can only oscillate to a certain extent, from which its deviation must be extremely limited; the mean motions of rotation and revolution of these different bodies are uniform, and their mean distances to the foci of the principal forces which animate them, are uniform. It seems that nature has disposed everything in the heavens to insure the duration of the system by views similar to those which she appears to us so admirably to follow upon earth, to preserve the individual and insure the perpetuity of the species."

The following observations upon this subject are derived from the Bridgewater Treatise already referred to, p. 181:

"La Place conjectures that in the original condition of the solar system, the sun revolved upon his axis, surrounded by an atmosphere which, in virtue of an excessive heat, extended far beyond the orbits of all the planets, the planets as yet having no existence. The heat gradually diminished, and as the solar atmosphere contracted by cooling, the rapidity of its rotation increased by the laws of rotatory motion, and an exterior zone of vapour was detached from the rest, the central attraction being no longer able to overcome the increased centrifugal force. This zone of vapour might in some cases retain its form, as we see it in Saturn's ring; but more usually the ring of vapour would break into several masses, and these would generally coalesce into one mass, which would revolve about the sun. Such portions of the solar atmosphere, abandoned successively at different distances, would form 'planets in the state of vapour.' These masses of vapour, it appears from mechanical considerations, would have each its rotatory motion, and as the cooling of the vapour still went on, would each produce a planet, which might have satellites and rings, formed from the planet in the same manner as the planets were formed from the atmosphere of the sun.

"It may easily be conceived that all the primary motions of a system so produced would be nearly circular, nearly in the plane of the original equator of the solar rotation, and in the direction of that rotation. Reasons are offered also to show that the motions of the satellites thus produced and the motions of rotation of the planets must be in the same direction. And thus it is held that the hypothesis accounts for the most remarkable circumstances in the structure of the solar system: namely, the motions of the planets in the same direction, and almost in the same plane; the motions of the satellites in the same direction as those of the planets; the motions of rotation of these different bodies still in the same direction as the other motions, and in planes not much different; the small eccentricity of the orbits of the planets, upon which condition, along with some of the preceding ones, the stability of the system depends; and the position of the source of light and heat in the centre of the system."

Such then is the *original* nebular hypothesis which has received collectively four kinds of illustration; the first, from the observed aggregations of solar systems; the second, from the appearance and disappearance of stars; the third, from the phenomena of the ring of Saturn, cometary matter, the zodiacal light, &c.; and the fourth, from certain alleged irresolvable nebulæ, but which are now said to be resolvable, in consequence of further discoveries by means of Lord Rosse's telescope, so that we may dispense with the last illustration.

In his Address to the British Association, Sir J. Herschel thus refers to the several illustrations which we have divided into classes.*

"Now, among all the wonders which the heavens present to our contemplation, there is none more astonishing than such close compacted families or communities of stars, forming systems either insulated from all others, or in binary connexion, as double clusters whose confines intermix, and consisting of individual stars nearly equal in apparent magnitude, and crowded together in such multitudes as to defy all attempts to count or even to estimate their numbers. What *are* these mysterious families? Under what dynamical conditions do they subsist? Is it conceivable that they can exist at all, and endure under the Newtonian law of gravitation without perpetual collisions? And, if so, what a problem of unimaginable complexity is presented by such a system if we should attempt to dive into its perturbations and its conditions of stability by the feeble aid of our analysis. The existence of a luminous matter, not congregated into massive bodies in the nature of stars, but disseminated through vast regions of space in a vaporous or cloud-like state, undergoing, or awaiting the slow process of aggregation into masses by the power of gravitation, was originally suggested to the late Sir W. Herschel in his reviews of the nebulæ, by those extraordinary objects which his researches disclosed, which exhibit no regularity of outline, no systematic gradation of brightness, but of which the wisps and curls of a cirrhus cloud afford a not inapt description. The wildest imagination can conceive nothing more capricious than their forms, which in many instances seem totally devoid of plan as much so as real clouds,—in others, offer traces of a regularity hardly less uncouth and characteristic, and which in some cases seems to indicate a cellular, in others a sheeted structure, complicated in folds as if agitated by internal winds.

---

* *Athenæum*, June 21, 1845, p. 615.

"Should the powers of an instrument such as Lord Rosse's succeed in resolving these also into stars, and, moreover, in demonstrating the starry nature of the regular elliptic nebulæ, which have hitherto resisted such decomposition, the idea of a *nebulous matter*, in the nature of a shining fluid, or condensible gas, must, of course, cease to rest on any support derived from actual observation in the sidereal heavens, whatever countenance it may still receive in the minds of cosmogonists from the tails and atmospheres of comets, and the zodiacal light in our own system. But though all idea of its being ever given to mortal eye, to view aught that can be regarded as an outstanding portion of primæval chaos, be dissipated, it will by no means have been even then demonstrated that among those stars, so confusedly scattered, no aggregating powers are in action, tending to draw them into groups and insulate them from neighbouring groups; and, speaking from my own impressions, I should say that, in the structure of the Magellanic Clouds, it is really difficult not to believe we see distinct evidences of the exercise of such a power. This part of my father's general views of the construction of the heavens, therefore, being entirely distinct from what has of late been called 'the nebulous hypothesis,' will still subsist as a matter of rational and philosophical speculation,—and perhaps all the better for being separated from the other.

"Much has been said of late of the nebulous hypothesis, as a mode of representing the origin of our own planetary system. An idea of La Place, of which it is impossible to deny the ingenuity, of the successive abandonment of planetary rings, collecting themselves into planets by a revolving mass gradually shrinking in dimension by the loss of heat, and finally concentrating itself into a sun, has been insisted on with some pertinacity, and supposed to receive almost demonstrative support from considerations to which I shall presently refer. I am by no means disposed to quarrel with the nebulous hypothesis even in this form, as a matter of pure speculation, and without any reference to final causes; but if it is to be regarded as a demonstrative truth, or as receiving the smallest support from any observed numerical relations which actually hold good among the elements of the planetary orbits, I beg leave to demur. Assuredly, it receives no support from observation of the effects of sidereal aggregation, as exemplified in the formation of globular and elliptic clusters, supposing *them* to have resulted from such aggregation. For were this the cause, working itself out in thousands of instances, it would have resulted, *not* in the formation of a single large central body, surrounded by a few much smaller attendants, disposed in one plane around it,—but in systems of infinitely greater complexity, consisting of multitudes of nearly equal luminaries, grouped together in a solid elliptic or globular form. So far, then, as any conclusion from our observations of nebulæ can go, the result of agglomerative tendencies, *may*, indeed, be the formation of families of stars of a general and very striking character; but we see nothing to lead us to presume its further result to be the surrounding of those stars with planetary attendants. If, therefore, we go on to push its application to that extent, we clearly theorize in advance of all inductive observation.

"But if we go still farther, as has been done in a philosophical work of much mathematical pretension, which has lately come into a good deal of notice in this country, and attempt 'to give a mathematical consistency' to such a cosmogony by the '*indispensable criterion*' of 'a numerical verification,'—and so exhibit, as 'necessary consequences of such a mode of formation,' a series of numbers which observation has established independent of any such hypothesis, as primordial elements of our system—if, in pursuit of this idea, we find the author first computing the time of rotation the sun must have had about its axis so that a planet situate on its surface and forming a part of it should not press on that surface, and should therefore be in a state of indifference as to its adhesion or detachment—if we find him, in this computation, throwing overboard as troublesome all those essential considerations of the law of cooling, the change of spheroidical form, the internal distribution of density, the probable non-circulation of the internal and external shells in the same periodic time, on which alone it is possible to execute such a calculation correctly; and avowedly, as a short cut to a result, using as the basis of his calculation 'the elementary Huyghenian theorems for the evaluation of centripetal forces in combination with the law of gravitation;'—a combination which, I need not explain to those who have read the first book of Newton, leads direct to Kepler's law;—and if we find him then gravely turning round upon us, and adducing the coincidence of the resulting periods compared with the distances of the planets with this law of Kepler, as *being* the numerical verification in question,—where, I would ask, is there a student to be found who has graduated as a Senior Optime in this University, who will not at once lay his finger on the fallacy of such an argument, and declare it a vicious circle."

With regard to the observed aggregations of solar systems, Sir J. Herschel remarks in his *Treatise upon Astronomy,* p. 400, referring to certain clusters of stars:

"Their round figure clearly indicates the existence of some general bond of union in the nature of an attractive force; and, in many of them, there is an evident acceleration in the rate of condensation as we approach the centre, which is not referable to a merely uniform distribution of equidistant stars through a globular space, but marks an intrinsic *density* in their state of aggregation, greater at the centre than at the surface of the mass. It is difficult to form any conception of the dynamical state of such a system. On the one hand, without a rotatory motion and a centrifugal force, it is hardly possible not to regard them as in a state of progressive collapse. On the other, granting such a motion and such a force, we find it no less difficult to reconcile the apparent sphericity of their form with a rotation of the whole system round any single axis, without which internal collisions would appear to be inevitable."

Now on this subject Swedenborg observes in his First Chapter in Part III., Vol II., *On the Comparison of the Sidereal Heaven with the Magnetic Sphere,* p. 229, that the forms of sidereal aggregations are diversified forms of magnetic spheres; that these spheres of incalculable immensity have their type on a small scale in the sphere of the common magnet; hence that they have their poles, axes, equators, and ecliptics; and all these variously modified according to the situation and intermingling of the several spheres, all of which again are only components of one common sphere.

The following view of the subject has since been intimated by Mr. Robert Young in the *Essay on Motion,* to which we have already referred. In the chapter on the constructive analogy between the primary corpuscles, the planets with their systems, the solar system, and the fixed stars, p. 202, he observes:

"The term solid is applied to a species of being having a determinate character, that is, a circumscribed resistance; not to any fixed degrees of that resistance. As there may be invisible solids, like air discovered by the touch, so there may be intangible ones, discovered by inference from other phenomena. Tangibility belongs to that degree of resistance, in solids, which is capable of producing a certain change on such solids as our organs: a less degree will fail of being manifest to our touch; but philosophers are abundantly convinced, that one sense is not the criterion of existence, but such inferences as result from the testimony of all. It is the property of fire to give the feeling of heat, but not of all degrees of fire; for we are assured of the presence of fire in bodies, which are cold to our sense. Light may be proved to exist, where the eye would announce a total darkness.

"In like manner, matter has its degrees of intensity. Water is less dense than stone, air than water, vapour than air, light than vapour; and as light is intangible, excepting to the optic nerve, why may not matter still less dense than light exist, to us invisible as well as intangible?

"We shall not, therefore, be misunderstood, when we say the planetary spheres are material, that we think them gross, like the matter around us, or that we adopt the solid orbs of the Ptolemaic system, or the dense substance of the vortices of Des Cartes. But we say the celestial orbits exhibit evident proofs of their being *circumscribed extensions, resisting on all sides,* and inert; and of having, thus, the characteristics of matter, and being altogether similar to sensible bodies, except a difference in degree.

"We know from observation, that a sphere of activity extends to some distance around our earth: and we shall consider it as a *datum* that similar spheres extend around all the planets, and the sun; by which they interchange a mutual influence; and also, about the fixed stars, although their agency is less apparent to us. To what limits these spheres of activity extend, about each celestial body, we do not here inquire.

"The phenomena of falling bodies in different parts of the atmosphere surrounding our earth may serve to illustrate the distinction we wish to have clearly understood, between the part of an atom, and the whole. Since, on every part of the earth's surface, bodies fall, the agency, therefore, by which they fall, extends all round the earth. The whole of this sphere of agency we call a sphere of matter, less dense than our earth, and enveloping it; but if we speak of any separate part, we call it immaterial. Thus it is an *immaterial* substance and agency which causes a stone to fall; because this is done by a portion of the sphere: in each portion the sphere is active, in the whole inert; in *each part immaterial, as a whole, a material* but rare and subtile orb.

"The unity and order of each distinct system, and of the entire universe, demonstrate a mutual resistance to each other, and, at the same time, a mutual attachment of these spheres of activity.

"The earth and moon, in their revolution about the sun, carry along with them their respective spheres of activity: but neither penetrates, nor is penetrated by the other. The same may be said of Jupiter and Saturn, with their moons; and all the planets, with the sun, revolving about their common centre, preserve their distances from that centre; and since the very being of the universe depends upon every part preserving its proper distance from every other, there can be no doubt but a powerful agency is prepared to *resist* any tendency, actual or possible, to the falling together of the celestial bodies.

"It is equally essential to the present state of things, that the planets are not too widely scattered asunder, as that they do not approximate too near; and that every part, planets, sun, and fixed stars, neither encroach upon each other's limits, nor any of them fly off, detached and lost from the system, into boundless space: hence it is as evident that there exists an *attaching* force to preserve the connexion and order of these parts, as it is that there exists a *propelling* power, to prevent their rushing together into one common mass.

"Without an attaching power, the unity of the whole could not be preserved; without a resisting, the distinctness of parts must be destroyed.

"This two-fold power, which is necessary to the existence of the larger planetary system, we have before shewn to be necessary to the existence of a single atom; that is, a resistance of the parts to a nearer approach, and to a more distant recess, and in this we perceive a perfect similitude between the nature of the general system, and of the smallest atom.

"If we regard any single sphere of activity, we may resemble it to a single atom. It is a complete existence in itself; a whole, formed of its own parts. Thus we may regard the sphere of the earth's activity, of the moon's, of Jupiter's, Saturn's, or the sun's.

"If we regard any of these spheres in their relation to other spheres, we may resemble them to atoms in their relation as cohering to other atoms.

"Thus the spheres of the earth and moon cohere together; of Jupiter and his satellites; of Saturn and his satellites; and these may be considered, again, as compound masses, which, together with the spheres of the other planets, all cohere with the sphere of the sun's activity, or are involved in it.

"Again, the whole sphere of our solar system *coheres* with contiguous spheres of the nearest fixed stars; and each of these immense orbs of activity may be regarded as an *atom,* in relation to the whole universe; and the universe as a *quiescent mass* constituted by the cohesion of these atoms, in a manner analogous to the formation of any small and more dense body, by its component atoms."

Again, p. 209:

"Respecting the cohesion of these spheres, we say they cannot hold each other together by any distant action; neither by simply coming in contact at their surfaces; but it is necessary that parts of two attached spheres should intersect each other, and that their substances at these intersecting parts should intermix, and their actions be blended in such sort as to constitute these conjoined portions, common to either sphere, the bond of attachment between both.

"In the celestial machinery there are two species of *attachment* to be traced. The *first* is that of spheres intersecting each other, in portions, the remaining portions extending without each other; the *second* species of attachment is when less spheres are *wholly contained* within greater.

"The sphere of our solar system can only be connected to the spheres of the fixed stars by intersection of portions of the spheres; but the smaller spheres of the planets belonging to our system, are contained, and wholly enveloped within that larger sphere.

"When any sphere of activity involves another sphere, in such a manner that the involved sphere is *singly* acted upon by the other, in which it is contained, it will necessarily follow that this contained sphere will be carried about the centre of the other sphere, by the revolving motion of that other; or, that each sphere will be carried about a common centre by the conjoined revolving motions of each.

"From hence the revolutions, both of the primary and secondary planets, ascertained by observations, might be demonstrated *à priori,* could their relative distances be ascertained, independent of the knowledge of their motions.

"The moon and earth, by their vicinity, ought to revolve, by the mutual actions of their spheres of activity, about a centre common to both.

"The same may be said of the other satellites, respecting their primaries.

"All of these, primaries and secondaries, being involved within a larger and parent sphere, ought to be carried about a common centre, by that larger vortex."

Again, p. 279:

"The subtile revolving fluid, the centre of whose vortex the earth occupies, not only surrounds, but pervades the earth, and other vortices their earths, to their centres; and the earth and planets are, by its revolutions, carried around on their own axes."

Swedenborg moreover observes that the axis of our own universe is in the galaxy; that here consequently the magnetic power is the strongest, and hence that here we find the greatest condensation of solar systems; that our own sun is not in this axis but a little out of it, and hence the original cause of the ellipticity of the planetary orbits, which he supposes to be attracted in the direction of the axis of the common sphere.

Sir David Brewster in his *Treatise on Magnetism,* p. 264, observes:

"The following speculations on this curious subject are hazarded by M. Hansteen, in his work on the magnetism of the earth. 'For these reasons, it appears most natural to seek their origin in the sun, the source of all living activity; and our conjecture gains probability from the preceding remarks on the daily oscillations of the needle. Upon this principle, the sun may be conceived as possessing one or more magnetic axes, which, by distributing the force, occasion a magnetic difference in the earth, in the moon, and all those planets whose internal structure admits of such a difference. Yet, allowing all this, the main difficulty seems not to be overcome, but merely removed from the eyes to a greater distance; for the question may be still asked with equal justice, *whence did the sun acquire its magnetic force?* And if from the sun we have recourse to a central sun, and from that again to a general magnetic direction throughout the universe, having the milky-way for its equator, we but lengthen an unrestricted chain, every link of which hangs on the preceding link, no one of them on a point of support.'"

Now Professor Hansteen has here observed, "that if we refer to a general magnetic direction throughout the universe, having the milky-way for its equator, we but lengthen an unrestricted chain, every link of which hangs on the preceding link, no one of them on a point of support." If this observation was designed to extend to the theory of Swedenborg, we may observe that Swedenborg does not regard the milky-way as the equator but as the axis; but whether it be the equator or the axis, both derive their magnetism from the suns composing them. But whence again did these derive their magnetism? the answer is, from the primordial particles of which the suns are composed, not from some *other* sun, nor from some *other* equator, nor from some *other* axis; thus not from without but from within; that is to say, from the first natural point finited by the Infinite.

But Professor Hansteen thus continues, p. 265:

" 'All things considered, the following mode of representing the subject appears to me most plausible. If a single globe were left to move alone freely in the immensity of space, the opposite forces existing in its material structure would soon arrive at an equilibrium conformable to their nature, if they were not so at first, and all activity would soon come to an end. But if we imagine another globe to be introduced, a mutual relation will arise between the two; and one of its results will be a reciprocal tendency to unite, which is designated, and sometimes thought to be explained, by the merely descriptive word attraction. Now, would this tendency be the only consequence of that relation? Is it not more likely that the fundamental forces, being driven from their state of indifference or rest, would exhibit their energy in all possible directions, giving rise to all kinds of contrary action? The electric force is excited, not by friction alone, but also by contact, and probably also, though in smaller degrees, by the mutual action of two bodies at a distance; for contact is nothing but the smallest possible distance, and that, moreover, only for a few small particles. Is it not conceivable that magnetic force may likewise originate in a similar manner? When the natural philosopher and the mathematician pay regard to no other effect of the reciprocal relation between two bodies at a distance, except the tendency to unite, they proceed logically, if their investigations require nothing more than a moving power; but should it be maintained that no other energy *can* be developed between two such bodies, the assertion will need proof, and the proof will be hard to find.

" 'I reckon it possible, therefore, that, by means of the mutual relations subsisting between the sun and all the planets, as well as between the latter and their satellites, a magnetic action may be excited in every one of those globes whose material structure admits of it, in a direction depending on the position of the rotatory axes with regard to the plane of the orbit. Each of the planets might thus give rise to a particular magnetic axis in the sun; but as their orbits make only small angles with the sun's equator and each other, these magnetic axes would, perhaps, on the whole, correspond with the several rotatory axes. Such planets as have no moons would, on this principle, have but one magnetic axis; the rest would, in all cases, have one axis more than they have moons, if those different axes, by reason of the small angles which the orbits of their several moons form with each other, did not combine into a single axis. The conical motions by which the rotatory axes of the planets are carried round the pole of the ecliptic (the precession in the earth), joined to the revolving motion of the orbits about the sun's equator, (which occasions the present diminution in the obliquity of the ecliptic,) might, perhaps, in this case, account for the change of position in the magnetic axis. It would greatly strengthen this hypothesis, if the above great magnetic period, after the lapse of which both axes again assume the same position, should in fact be found to coincide with the period of the precession, which, however, seems a little doubtful.' "

On this theory Sir David Brewster thus remarks:

"Such was the state of speculation on this part of the subject when Hansteen published his work on the magnetism of the earth. The poles of our globe were then regarded as the coldest parts on its surface; and no conjecture even had been hazarded regarding the connexion between the phenomena of terrestrial temperature and terrestrial magnetism, till Sir David Brewster proved, from an immense number of meteorological observations, that there were in our northern hemispheres two poles of maximum cold; that these poles coincided with the magnetic poles; that the circle of maximum heat, like the magnetic equator, did not coincide with the equinoctial line; that the isothermal lines, and the lines of equal magnetic density, had the same general form surrounding and enclosing the magnetic poles and those of maximum cold; and that, by the same formula, *mutatis mutandis*, we could calculate the temperature and the magnetic intensity of any point of the globe. These views we have referred to more fully in the history of magnetism.

"The monthly and daily changes in the intensity of terrestrial magnetism, and in the dip and variation of the needle, had led Canton and others to ascribe these changes to the action of the sun; and Captain Duperrey, in his paper on the magnetic equator, has ascertained, that the points of this great circle, or those where the magnetic intensity is a minimum, are also the warmest points of each meridian, or that the thermal and the magnetic equator are connected, as we had already proved to be the case with the thermal and magnetic poles. Captain Duperrey likewise attributes the differences in the magnetic intensities of different places to their difference of temperature; and he remarks, that in comparing the isothermal and the isodynamic lines, he has found a remarkable analogy in their curvatures, and particularly in the direction of their concavities and convexities. In support of these views, Captain Duperrey refers to the changes in the daily variation, as following the movements of the sun; and he infers that the southern hemisphere of our globe is a degree colder than the northern hemisphere.

"But though it is now placed beyond a doubt, that the phenomena of temperature and magnetism are closely connected, and that the latter are powerfully influenced by the former, yet various questions arise, which it is very difficult to answer."

These extracts we have added without comment for the purpose of communicating to the general reader some idea of the present state of speculation upon the subject. We shall only observe, although a more particular reference to Swedenborg's theological works might not be desirable here, lest it might seem to mix up theological verities with possibly physical errors, that in his theological writings Swedenborg maintains, that *the constitution of the visible heavens never can be understood without first understanding the constitution of the invisible.* That the invisible are far more immense than the visible, of which the Lord is the one only and central sun; that they consist of distinct ordinations of angelic hosts or societies into the human form, according to the apostolic idea of the constitution of a church; that every distinct society has its distinct place in the universal body; that united into one it exhibits the splendour of a spiritual star to which there is a corresponding natural sun; that natural suns are aggregated or grouped according to their correspondencies to the spiritual; thus that the natural is the outbirth of the spiritual, the visible of the invisible, the temporal of the eternal, the finite of the infinite; and that the concentrations and dispersions of universes is but the outward manifestation of the changes going on in the inward and spiritual heavens, which refer to ever new varieties of state in consequence of ever new progressions from glory to glory.

With regard to the second class of illustrations, or the appearance and disappearance of stars, this is the one and the only one which is adduced by Swedenborg. Of these stars there are said to be two classes; the one whose appearance and disappearance are periodical, and which are consequently thought to indicate only rotation about an axis. These, however, must be distinguished from the other class of stars, which appear and disappear, and of whose reappearance no record exists.

With regard to the third class of illustrations, nothing has hitherto tended to discredit them, and consequently they may fairly be adduced by the cosmogonist in confirmation of the original theory; but Swedenborg is silent upon the subject. We refer to the ring of Saturn, the zodiacal light, and the phenomena of comets. The fourth illustration, or the one derived from supposed irresolvable nebulæ, has recently been considered to have no foundation in fact, and as Swedenborg does not allude to it, the subject may be dismissed.

We now proceed to a more direct comparison of Swedenborg's cosmogonical theory with that of La Place.

After the suggestions of Newton upon this subject, with the existence of which I know not whether La Place was acquainted, it was asserted by the latter that Buffon was the first writer whom he knew, who, since the discovery of the true system of the world, had attempted to investigate the origin of the planets and their satellites. Now Swedenborg published his *Principia* in the year 1734; that is to say, ten years *before* Buffon published his theory, and Buffon himself had read Swedenborg's *Principia,* as may be concluded from the circumstance that a copy of Swedenborg's *Principia* was not very long since sold by an eminent bookseller* in London, containing Buffon's own autograph; therefore if La Place himself was not acquainted with Swedenborg's treatise, it is reasonable to presume that Buffon was. Ten years, then, before Buffon published his theory, and about thirty years before La Place offered his own to the public, Swedenborg had propounded his theory in the *Principia,* in the year 1734; and again in his treatise on the *Worship and Love of God,* in the year 1745, or about twenty years before La Place's theory.

---

* The late Mr. Bohn of Henrietta Street, Covent Garden.

In these two works it had been observed by Swedenborg, that the sun is the centre of a vortex; that it rotates upon its axis; that the solar matter concentrated itself into a belt, zone, or ring at the equator, or rather ecliptic; that by attenuation of the ring it became disrupted; that upon the disruption, part of the matter collected into globes, and part subsided into the sun forming solar spots; that the globes of solar matter were projected into space; that consequently they described a spiral orbit; that in proportion as the igneous matter thus projected receded from the sun, it gradually experienced refrigeration and consequent condensation; that hence followed the formation of the elements of ether, air, aqueous vapour, &c., until the planets finally reached their present orbit; that during this period the earth experienced a succession of geological changes which originated all the varieties in the mineral kingdom, and laid as it were the basis of the vegetable and afterwards of the animal kingdoms. This is the general view of Swedenborg's cosmogonical theory, with which Buffon was acquainted, but of which La Place, according to his own account, was ignorant.

Now the points of difference and agreement between the theory of La Place and that of Swedenborg are the following. Swedenborg begins at the centre, La Place at the circumference. Swedenborg traces the process of creation from the centre to the circumference, La Place traces it from the circumference to the centre. According to Swedenborg, the centre created the circumference; according to La Place, the circumference created the centre. On the other hand, both agree that the planets were formed by a condensation of zones, and hence that planetary matter was originally solar. The latest experiments are unfavourable to the order observed by La Place and favourable to the order observed by Swedenborg. Thus in the *Explanations* we meet with the following remarks, p. 13:

"Here it is peculiarly important to bear in mind, that the phenomena of nature are, if I may so speak, indifferent to the scale on which they act. The dew-drop is, in physics, the picture of the world. Remembering this, we are prepared in some measure, to hear of a Belgian professor imitating the supposed formation and arrangement of a solar system, in some of its most essential particulars, on the table of a lecture-room! The experiments were first conducted by Professor Plateau of Ghent, and afterwards repeated by our own Dr. Faraday.

" The following abstract of Professor Plateau's experiments is also presented in the fifth edition of the *Vestiges*. Its being repeated here is, that it may meet the eyes of many who are not likely to see any edition of that work besides those from which it is absent:

" Placing a mixture of water and alcohol in a glass box, and therein a small quantity of olive oil, of density precisely equal to the mixture, we have in the latter *a liquid mass relieved from the operation of gravity*, and free to take the exterior form given by the forces which may act upon it. In point of fact, the oil instantly takes a globular form by virtue of molecular attraction. A vertical axis being introduced through the box, with a small disk upon it, so arranged that its centre is coincident with the centre of the globe of oil, we turn the axis at a slow rate, and thus set the oil sphere into rotation. 'We then presently see the sphere *flatten at its poles* and *swell out at its equator*, and we thus realize, on a small scale, an effect which is admitted to have taken place in the planets.' The spherifying forces are of different natures, that of molecular attraction in the case of the oil, and of universal attraction in that of the planet, but the results are 'analagous, if not identical.' Quickening the rotation makes the figure more oblately spheroidal. When it comes to be so quick as two or three turns in a second, 'the liquid sphere first takes rapidly its maximum of flattening, then becomes hollow above and below, around the axis of rotation, stretching out continually in a horizontal direction, and finally abandoning the disc, is *transformed into a perfectly regular ring*.' At first this remains connected with the disk by a thin pellicle of oil; but on the disc being stopped this breaks and disappears, and the ring becomes completely disengaged. The only observable difference between the latter and the ring of Saturn is, that it is rounded, instead of being flattened; but this is accounted for in a satisfactory way.

" A little after the stoppage of the rotatory motion of the disc, the ring of oil, losing its own motion, gathers once more into a sphere. If, however, a smaller disc be used, and its rotation continued after the separation of the ring, rotatory motion and centrifugal force will be generated in the alcoholic fluid, and the oil ring, thus prevented from returning into the globular form, divides itself into '*several isolated masses, each of which immediately takes the globular form*.' These are 'almost always seen to assume, at the instant of their formation, a *movement of rotation upon themselves*—a movement which constantly takes place *in the same direction as that of the ring*. Moreover, as the ring, at the instant of its rupture, had still a remainder of velocity, the spheres to which it has given birth tend to fly off at a tangent; but as, on the other side, the disc, turning in the alcoholic liquor, has impressed on this a movement of rotation, the spheres are especially carried along by this last movement, and revolve for some time round the disc. Those which revolve at the same time upon themselves, consequently, then present the curious spectacle of *planets revolving at the same time on themselves and in their orbits.* Finally, another very curious effect is also manifested in these circumstances: besides three or four large spheres into which the ring resolves itself, there are almost always produced one or two very small ones, which may thus be compared to satellites. The experiment which we have thus described presents, as we see, an image in miniature of the formation of the planets, according to the hypothesis of La Place, by the rupture of the cosmical rings attributable to the condensation of the solar atmosphere."

The objection urged by La Place to a projection of planets from the sun arose from his maintaining that according to the law of gravitation a planet projected from the sun must either fall back into it or else describe a very eccentric orbit. But La Place did not maintain the doctrine of vortices, otherwise the conclusion might have been different; nor did he maintain the doctrine of a central first cause.

Now the foregoing theory of Cosmogony has been opposed upon the ground, that God created all things out of *nothing*; a doctrine which has been religiously and zealously espoused. Hence probably one reason why the present work of the *Principia* has been placed by the Papal authority in the *Index Expurgatorius.* Another reason for this may be inferred also from the difficulty of reconciling such a process of creation with the literal interpretation of the first chapter in Genesis. With regard to the first objection, there seems to be now a conviction among a large class of divines that the doctrine of instantaneous creation out of *nothing* has no foundation in Scripture, as may be inferred from Dr. Buckland's *Bridgewater Treatise,* &c. But besides this, the doctrine is open to another objection. No definition is more common than that truth is that which is, hence in a corresponding sense, untruth, error, or falsehood is that which is not; and consequently that which is the genuine nonentity—or, *nothing.* Upon this ground, to say that God created all things out of *nothing,* is to attribute the origin of all things to error and hence to evil. With regard to the second objection, that such a view militates against the literal interpretation of

Genesis, it may be replied that some of the fathers interpreted the early chapters of Genesis allegorically, so that there is a precedent for Swedenborg's interpretation of them in a spiritual sense. Of this sense, however, he was ignorant when he wrote the *Principia,* and hence his occasional attempts to reconcile his theory with the literal interpretation of the Mosaic narrative. What are the nature and extent of the correspondence between the spiritual creation of man, and the natural creation of the world, will be best ascertained when the true theory of Cosmogony has been finally determined. In the meantime the reader of Swedenborg's theological writings will continue to interpret the first chapter of Genesis as designed to apply to the former and not to the latter; consequently he will feel himself perfectly free from the perplexities and embarrassments of modern theologians.

There is, however, another objection to the foregoing theory of Cosmogony which has been zealously entertained, namely, that all things were created instantaneously by an arbitrary *fiat.* But the doctrine here introduced into physics it is well known has been likewise introduced into morals. Ockham, for instance, maintained that good and evil derived their distinctions from a similarly arbitrary exercise of the divine will; hence that good and evil were not essentially different, but different only on account of the command of God, who, had he so pleased, might have made that evil which we now call good, and that good which we now call evil; thus when all things were created, and God saw all that he had made and behold it was very good, that the good resulted from a mere arbitrary *fiat.* Now to say nothing of the fallacies here implied, we may observe, that upon this principle all creation is referred to the Divine Will, to the exclusion of Divine Wisdom. But wisdom is truth and order and law, whence all of these are excluded; so that it is this doctrine of an arbitrary *fiat* which is the truly irreligious doctrine, because it is opposed to Scripture and denies the prerogatives of Divine Wisdom; nay, it excludes Divine Omnipotence, for omnipotence is Divine Truth in operation. It is thus altogether opposed to Scripture; for we are expressly told that it is "The *Word* that made all things, and that without Him was not anything made that was made." Thus it leads to an entire ignorance of God, because it attributes all to *will* and nothing to *wisdom,* although it is only through the wisdom of God that we can know anything of His will; and moreover if this doctrine of arbitrary will has subverted the laws of common morality, why should we admit it as a faithful expositor of the laws of nature?

But there is another objection to the foregoing theory of Cosmogony. It has been maintained that it substitutes the agency of secondary causes for the agency of the Great First Cause; that creation is assigned to vortices and suns instead of to the agency of God. To this it has been replied in the *Bridgewater Treatise* to which we have referred, that after all even nebulæ and suns must have their origin, and so we may add must also vortices; that consequently even on this hypothesis we are referred to an original Great First Cause, the Creator of vortices and of suns. But this is not all; the lowest effect produced by the lowest cause in the order of secondary causes, is as truly the work of God as if there had been no secondary cause at all. For God is not only the First but He is the Last; He is not only the Alpha but the Omega of creation; and hence He is present in the last effect as veritably as in the first of secondary causes, and as truly originates the lowest effect, as He does the highest created cause; therefore could the series of creative processes be traced far higher than solar or vortical agency, we should not in so tracing them be departing from Him; for still we might ask, "*Whither shall we go from Thy presence?* If we ascend up to heaven Thou art there; if we go down into hell, Thou art there also." If we ascend up to the nebulæ of stars, He is there; if we descend to the vilest worm, He is there also. Even the veriest weed that roots itself in the lowest depths of the ocean, has its God, the same God who is God of the glorious worlds above, visible and invisible; "God over all blessed for ever."

But in what way can the Creator thus be present in creation? We answer, in the ends for which they were created, as well as in the beginning from which they were created, for God is not only the Beginning, but is also the End. It is for the accomplishment of these ends, the lowest of which transcends the highest human wisdom, that each created form is endowed with such a wonderful organization; such a beautiful complication of structure. What is the structure of man says Swedenborg, but a living mass of miracles? We have the supernatural in the lowest effect as truly as in the highest created cause. It is only because the mind does not recognize the divine operation in the ordinary laws of nature, that it is attributed only to higher and secondary causes, or to some immediate Divine interposition to their exclusion. But if we banish God from the lower regions of creation, he will soon be banished from the higher; if we exclude him from effects, and confine him only to causes, he will soon be excluded even from causes themselves. True it is that science has traced out the operation of secondary causes, where it was thought divine agency alone existed: it has been asserted, moreover, that certain secondary causes of things are unsearchable, such as the origin of plants, of animals, and of man. But the reason is, that nothing is generally known of the spiritual world; for if this were known, these subjects would not necessarily be mysteries. For God creates the visible through the medium of the invisible; and hence it is that Swedenborg says, that nothing can be truly known of the visible world without a knowledge of the invisible. For the visible world is a world only of effects; it is the invisible world which is the world of causes; and it is no more presumptuous to enquire into the operations of the spiritual world, than it is to enquire into causes. Indeed the very circumstance that science has now led us upward in the history of creation to the very confines of creative power, and placed us there upon the very verge of the world of causes, seems to indicate that man has now at length arrived at that stage of enquiry in which the world of causes may be laid open to his view, in which consequently he may trace the connection between cause and effect, the invisible and the visible, spirit and body, mind and matter. It is thus only that we can be led to a perception of true and living wisdom. Separately from the invisible, the science of the natural world leads us only to eat of the tree of the knowledge of good and evil; which is indeed the very state to which the late Bishop Horne was of opinion that the world in his time had arrived. Let us therefore no longer separate the visible from the invisible; no longer listen to the tempter who would lead us to believe that truth is to be found only in a collection of facts evidenced by the senses, and that all beyond is speculation, phantasy, and imposture. No! "the candles of night are burnt out," the morning is breaking forth from the hills, the voice of thanksgiving already ascends from many an awakened spirit, Divine Truth like the sun is gradually revealing its orb above the horizon.—Let us rejoice and give thanks.

N.B. The reader has before been reminded that the present translation has been offered to his notice, only with the view that its contents may be carefully examined. It remains for him well to consider how far the objections urged in the different quotations presented in the foregoing pages, are of any serious importance. When these points have been better ascertained, and the recent discoveries in magnetism undergone further consideration, the Principia of Swedenborg may then be capable of a higher order of Introduction than the merely temporary one now presented by the translator.

SERENISSIME PRINCEPS

LUDOVICE RUDOLPHE,

DUX BRUNSVICENSIUM ET LUNEBURGENSIUM,

ETC. ETC.

ANTIQUIS ritus fuerat, si aliquis illorum ex numero Deus votis annueret, sive thure aræ ejus injecto litaret, quod voti sui compotes facti vel solverent quod voverant, vel sertis, verbenis, et vittis aras ejus cingerent; sique opulenta fuisset domus, quod bidentes ad altaria ejus mactarent; vel annua vel menstrua vota solennesque pompas ducerent; si vero pauperes essent Lares, quod aliquibus farris aut thuris flavi micis foco altaris ejus injectis, devoto magis animo et mussitante simul ore, sacra facerent, et ei grates agerent, et pro exiguis illis donis, ut iterum vota sua secundaret, precari ausi essent: verbo secundum rei familiaris sortem et fortunam, templis ejus tanquam sui tutelaris, et inter numerum deorum maxime faventis, propitii et secundantis, honores instaurabant, et altaria donis struebant. Ipse, cum ante duodecim quod excurrit annos, Vestræ Serenitati aliquas micas hujus farris sive tenues pagellas rudis et incomtæ Minervæ porrigere ausus sim, læte recordor, quod illis visis, tamen annuere et favere dignatus sis; quod cum mihi voti secundi argumentum fuerat, hinc, sed ignoscas, secundum ritum antiquorum, ad aram Tuam redeo, et quamvis non divites honores templis indicere, bidentes niveos mactare et Tibi pompas ducere queam, usque tamen acerram jam thure ejusdem generis sed pleniorem in grati animi pignus porrigere ausim; quumque litaverint olim micæ tantummodo illius farris porrectæ, spero id iterum, acerra pleniore jam muneri votivo oblata: permitte ergo, ut opusculum hoc Principiorum novorum plenum Te ut sui Tutelarem adoret, utque Philosophia hæc nova, ante Tuas aras, Tibi sacra et votiva, quum melioribus donis operari nequeo, veniat. Non orbem literatum latet, qualis Minervæ et literarum ejus Cultor et Amator sis, qualis cultorum ejus Tutela et Favor; his fretus propius propiusque accedere et veniam poscere ausim, et ut votis annuas, precari; si iterum annuis et faves, voti secundi faustissima auspicia erunt. Vive Serenissime Dux tot annos, quot in templis et ad aras pro annis et salute Tua vota redduntur: quod devotissime precor

SERENITATIS VESTRÆ

Perhumillimus cultor
EMANUEL SWEDENBORG.

PREFACE,

EXHIBITING A COMPENDIUM OF OUR PHILOSOPHY.

I AM apprehensive lest, at the very outset of our philosophy, particularly its First Part, my readers should be deterred from proceeding further, when they meet with views which cannot but appear strange and foreign to those which are generally received; as also with such unusual phraseology as that of a *Finite,* an *Active,* an *Elementary,* &c.; terms which are unknown in any of our philosophical treatises; that is, which are not applied to the principles of mechanism, geometry, and the elementary world. For this reason it will be requisite, by way of preface, to present a general outline of our work, and thus a key to its contents.

Every one from the light of reason may perceive, that nature, conforming to principles of geometry, is ever pursuing a most simple course; a course proper to herself, and truly mechanical. He may likewise perceive, that all things in the world originate from what is uncompounded; consequently from one single fountain-head and one primitive cause; that this primitive cause is derived into the various things which are caused (a truth which necessarily follows, if further products are to be derived from those which have already been brought into being); also that no other cause could possibly have had existence than the one which had proceeded by genealogical descent, as it were, from its first parent or simple. This cause, therefore, must be latent in the first simple; and into the first ens derived from it, or into the first finite there must be derived a similar cause. Now since the world deduces its origin and subsequent increments, by a connected and contiguous series, from the first or single end through intermediates to another end; and since there must be present a cause, and indeed an efficient and active cause, before anything can be produced in a series; it follows that there must be a passive, an active, and as a product from both, a compound, or elementary; if therefore there be anything composite, it must consist of two principles, namely, a passive and an active; without which nature herself would be as it were in a state of celibacy or solitariness, destitute of progeny, without any new efficient, hence without effect, without series, without phenomena; in a word, without worlds. With this view of the subject then, I have endeavoured to evince that *in the Finite, which is the first in successive derivation from the Simple, is contained each principle, both passive and active,* from which, by the accession of a contingent or physical cause, arose the Composite or Elementary; and further, that in every derivative, whether a Finite, Active, or Elementary, there always coexists a similar cause, and consequently a similar faculty of producing an effect, namely, from the one into the other; thus as it were from one power into another, from one degree into another, and so on farther and farther; that in the derivatives therefore there is latent a principle similar to that which exists in the primitives; in composites a principle similar to that which exists in simples; in effects a principle similar to that which exists in causes; consequently also that nature in her various kingdoms, especially the elementary, is in the cause and in the effect simultaneously: so that from well known principles of mechanism, under the guidance of geometry and the faculty of reasoning analytically, we may, from an effect visible and posterior, safely draw our conclusions not only with regard to effects invisible and prior, but with regard to the very entities which are active and passive; nay to the very cause which is latent in all.

Let us then, in a few words, present the sum and substance of our philosophy; and in so doing begin from the first Simple. 1. We observe then, that in a Simple there is an internal state tending to a spiral motion, and consequently that there is in it a like conatus or endeavour to produce it. 2. That in the first Finite thence resulting, there is a spiral motion of the parts. The same obtains in the other elementary Finites, in all which there is thus a like principle. 3. That from this single cause there arises in every Finite a progressive motion of the parts, an axillary motion of the whole, and, provided there be no obstacle, a local motion of the whole. 4. That if there be a local motion, there arises thence an Active, similar to the agent producing it, and differing only in degree and dimension. Hence that we admit of entities only of a threefold degree, namely, Finites, Actives, and those which are compounded of the two, namely, Composites or Elementaries. With respect to Finites we affirm, that one is generated by the other; and that all the Finites of the genus thus arising, have the greatest possible similitude one to the other; and differ only in degree and dimensions. Hence the fifth Finite is similar to the fourth; the fourth to the third; the third to the second; the second to the first; the first to its own proper Simple: so that he who knows the nature of one knows the nature of all. In the same manner we affirm, that Actives have the greatest possible similitude the one to the other; that the fifth, fourth, third, second, and first Active are all of the same nature; differing only in dimension and degree, in the same way as Finites. That Elementaries also are similar one to the other, since they are compounded of the Finite and Active; the Finites occupying the superficies, the Actives occupying the interiors; that hence the first, second, third, fourth, and fifth Element are all similar one to the other; so that he who knows the nature of one knows the nature of all. We affirm, moreover, that in every Finite there are three motions, namely, a Progressive motion of the parts, an Axillary, and a Local motion, provided there be no obstacle; nor am I aware that in these extremely simple entities any other natural motions can be assigned, or, even if they could, that there are any other than such as I have mentioned; or whether granting the motions of these entities, which no rational person would I think deny, that any other could be assigned more convenient to nature. We observe again, that all these motions proceed from one fountain-head, or from one and the same cause, namely, from a spiral motion of the parts. This motion, inasmuch as it is the most highly mechanical, is also the most highly natural; being that in which, as is well known, the whole potency of nature and all mechanical force is inherent; and if it be granted that it is motion which is the cause of things, then no other motion can be admitted, in this case, than such as is most highly mechanical and most highly geometrical; for from its centre to its circumferences in space, a spiral is one perpetual ens, circular in all its dimensions; and as such it cannot possess in itself anything but what is most highly perfect, most highly mechanical and natural in its motion; being both as to the site of its parts and as to its motion most highly geometrical. In a Simple, however, in which there can be nothing substantial to be put in motion, nor any medium in which motion can exist, we must conceive that instead of a mechanical and geometrical motion, such as there is between parts and in a medium, there is as it were a total or pure motion, that is to say, a state and a conatus hence arising from a similar into a similar *quasi* motion; in which is latent the one only cause and primitive force that produced all the entities subsequently existing.

Inasmuch as in all its kingdoms the visible world is of so diversified an aspect, and consists and subsists in the series of parts successively and simultaneously arising, it cannot possibly have its termination in the same point in which it had its beginning; thus it cannot possibly have its termination in its own first or mediate series or line of progression, or in its first or second part; for were this the case, there would be no series in existence, neither would there be any ends; because there would be no distinctions into intermediates; consequently no element to constitute vortices; none to constitute ether or air; nothing to constitute fire; much less anything to constitute the innumerable parts of the mineral, vegetable, and animal kingdoms; in a word, there would be no world. Hence it is that, my first aim has been to demonstrate, that the first Finite derives its origin from the Simple; the second Finite from the first Finite; the third from the second; the fourth from the third; each being attended by a cause similar to that which exists in the primitive Simple, and which passes, by successive derivation, into the Finites. Hence I shew that a series of Finites thus springs from a Simple, or from the first Finite, in succession to the fifth Finite. These five Finites have a mutual relation to each other, are similar to each other, and differ only in degree and dimension, or in their ratio to each other according as they are raised to successively higher powers or degrees. Again; inasmuch as all Finites are capable of becoming Actives, or of performing gyres from a like inhering and concomitant force or cause, that is to say, from a spiral motion of the parts; and inasmuch as they can pass also into a Local motion, provided there be space and nothing in it to present any obstacle; it follows of course, that there may be a fivefold series of Actives; an Active of the first, second, third, fourth, and fifth Finite points respectively; and hence that by means of the last or fifth Active, the fire of our system may pass into our atmosphere. The same law obtains in regard to the compounds or Elementary particles; which I hold to consist of two principles, namely, Actives and Finites; the Finites occupying the surface, the Actives occupying the interiors. And inasmuch as there is thus a series of Finites and of Actives, there will also be a series of Elements such as the first or most universal Element, the second or Magnetic or vortical Element, the third or Ethereal Element, the fourth or Aërial Element; before the elementary kingdom belonging to the world has yet been fully completed. And since every single particle of each Element is elastic, encloses Actives, and possesses the faculty [*vi*] of passivity and activity; hence the first Element encloses within it the Actives of the first Finite; the second, the Actives both of the first and second; the third, the first Elementary particles; the fourth, both the first and second Elementary particles; the two latter Elements participating in each principle, although they enclose not real Actives but Elementary particles. For the Elementary particles are not only passive but active; they are consequently elastic, and are moveable in particles and volumes; the motion and mechanism of their volume depending upon the motion and mechanism of their particles; although they are not mobile and elastic in the same degree as the enclosed first and second Elementary particles from which they receive their elasticity. Thus we shew that the Elements also differ in degrees and dimension, progressing equally with the Finites, &c., in a certain order and succession.

The series of these several subjects will be found in the work itself, as follows :—On the means of attaining to a True Philosophy. On the first simple or first natural Point. On the first Finite. On the second Finite. On the third Finite. On the fourth Finite. On the fifth Finite. On the pure material Finite, or Water.

With respect to the Actives, the series is as follows :—On the Active of the Point. On the Active of the first Finite. On the Actives of the second and third Finite. On the Actives of the fourth and fifth Finite, or on Fire.

With respect to the Elements, the series is as follows :—On the first or most universal Element. On the second or Magnetic Element. On the third Element, or the Ether. On the fourth Element, or the Air. On the fifth product similar to the Elements, or on Aqueous Vapour; where we finally show, that in every drop of water is contained every single thing which had hitherto existed from the first Simple, as also the whole genus of Finites, Actives, and Elementaries; consequently that in a single drop of water is latent the whole Elementary world both visible and invisible.

Now since causes and things caused are similar to each other, although they differ in degree and dimension, it follows that nature is similar to herself, and cannot be different in the larger system or elementary kingdom from what she is in the lesser; in the macrocosm from what she is in the microcosm; in a volume from what she is in a particle; hence in the elementary particle may be seen the quality of the volume, and in the volume the quality of the particle; from which we infer that the sun consists of the Actives which first originate, or those of the first and second Finite; particularly since it is the cause of all the subsequent mutations; the first motor of the things in its series; inasmuch as other things could not have successively existed except from the first Actives, or the solar space consisting of them. Consequently that the solar vortex and the vortex of the other stars consists of the first and second, hence of the most universal, Elements. That the sun itself, in the formation of its vortex, being surrounded with a crust of Finites of the fourth genus, was thus the original chaos of the earth and the planets; and inasmuch as this crust enclosed within it the sun, or the space consisting of the Actives of the first and second order, while the fourth Finites occasioned a pressure from without, such a chaos could resemble no other than an elementary particle; in which, in like manner, the Actives exercise a pressure from within, while the Finites or Passives occupy the surface; so that it was by a process the most simple that nature produced a chaos, from which she afterwards brought forth the earths; being thus similar to herself in her greatest as well as her smallest productions. That consequently the earth, when just produced, and in proximity with the sun, consisted of the fourth Finites, and possessed in the larger system, like the Finite in the smaller, a motion of its parts, an axillary motion, and also a local motion; so that in itself it was the representation of a large Finite; and as to its local and annual motion, the representation of a large Active; that hence both in the earth and in the other planets we may see what is the quality of the Finite and what the quality of the Active in its minute boundaries; and also in the chaos what is the quality of the elementary particle. These subjects however must be referred to in the work itself, where they are treated of under the following heads:—

On the existence of the sun and the formation of the solar vortex, Part I., Chap. x.

On the comparison of the starry heavens with the magnetic sphere, Part III., Chap. i.

On the diversities of worlds, Chap. ii.

On the universal chaos of the sun and planets, and the separation of its substance into planets and satellites, Chap. iv.

On the vortex surrounding the earth, and the progression of the earth from the sun to the circle of its orbit, Chap. xi.

On the paradisiacal state of this earth, and on the first man, Chap. xii.

In the course of these chapters may be seen what are the velocities, periodical times, and centripetal forces of the planets at their respective distances from their own proper sun; also what is the cause of the eccentricity of their orbits. How the earth passed through innumerable changes before it arrived at its ultimate orbit; how these changes were as innumerable as the circles through which it passed, or as the different distances of these circles from the sun, and its different degrees of velocity in its annual and diurnal circumvolution; in a word, how every day and hour it passed through some new change; how it was requisite for it to undergo these changes, before it could be fully perfected, or be made to consist of so many series of things arising simultaneously and successively, or be enriched with so many varieties so as to be complete in all its kingdoms, mineral vegetable, and animal, or could cherish seeds, unfold and expand them, and thus in so delightful and varied a manner adorn its own surface. In this state of the earth, while revolving upon its axis and gyrating round the sun more rapidly than at present; or while, in consequence of being nearer to its parent sun, it meted out shorter days and years; we shew how it must have been under the influence of a perpetual spring,—a season most peculiarly adapted to the process of begetting and procreating; without which, no seeds could have grown, nor any vegetable or animal productions have originated.

With respect to the magnet and its forces, the reader is referred to the whole of the Second Part of our treatise; where I attempt to demonstrate that its force arises from the motion of the first element and of the second or magnetic, out of which are formed the solar and planetary vortices. That its magnetism consists in effluvia, which are of such a nature as to be moveable round their own axis; and that these, when set in a gyrating or spiral motion, act as the subtile element which we call magnetism; consequently that by means of these gyrations arise little vortices and ligations of these vortices from one pole of the magnet or its sphere, to another pole; and that in this manner it is that magnetism is created, as also its conjunctive force when similar effluvia pervading any other body are brought into apposition with it. That the magnet itself as such, in regard to its interior texture, consists of a rectilinear or regular situation of its parts, extending from one polar side to the other; and that hence a sphere is formed extrinsically, connected on both sides with its axis by a mechanical necessity. That the effluvia or forementioned parts are purely iron, and that iron is rendered magnetical when those parts are brought interiorly, by friction against a magnet, either into a rectilinear or any other regular line.

We shew, moreover, that the declination of the magnet arises from the situation of these same particles of the first and second Element, or of the same element of which the vortices round the sun and the earth are formed; and that the magnet is directed into that same situation with its sphere in which are the very particles themselves of the forementioned element. That these elementary particles, inasmuch as at the same time they create a vortex round the earth must necessarily take a spiral course extending from one pole of the ecliptic to the other, and that hence arise the anomalies of magnetism.

See the Second Part of the Principia on the causes of the magnetic forces.

On the attractive forces of two or more magnets, and the ratio of the forces to the distances.

On the attractive forces of two magnets when their poles are alternated.

On the attractive forces of two magnets when their axes are parallel, or when the equinoctial of the one lies upon the equinoctial of the other.

On the disjunctive and repulsive forces of two or more magnets, when the cognominal or inimical poles are applied to each other.

On the attractive forces of the magnet and of iron.

On the influence of the magnet upon ignited iron.

On the quantity of exhalations from the magnet, and their penetration through hard bodies, &c.

On the various modes of destroying the power of the magnet; and on the chemical experiments made with it.

On the friction of the magnet against iron, and on the force communicated from the former to the latter.

On the conjunctive force of the magnet as exercised upon several pieces of iron.

On the influence of iron and the magnet upon the needle.

On the various modes of rendering iron magnetic.

On the declinations of the magnet as reduced to calculation.

Tables of observations of the declinations of the magnet in different places and at different times.

On the causes of the declination of the magnet.

Calculations of the declination of the magnet, in different years, at London and Paris.

Tables of the declinations of the magnet at Paris, from the year 1610 to 1920.

Calculations of the declinations of the magnet at Rome, at the Cape of Good Hope, and other places.

We may here add the chapter before enumerated—On the starry heaven, shewing that it is similar to the magnetic sphere: inasmuch as each is compounded of elementary particles of the same genus, most particularly adapted to vortical gyres, and being as it were born and made mechanically to the performance of this motion.

THE PRINCIPIA.

PART I.

January, 1846.

SWEDENBORG'S THEOLOGICAL WORKS.

BOOKS PUBLISHED BY THE SOCIETY FOR PRINTING & PUBLISHING THE WRITINGS OF THE HON. EMANUEL SWEDENBORG, INSTITUTED IN LONDON IN 1810.

AND SOLD AT THEIR DEPOSITORY BY

WILLIAM NEWBERY,

No. 6, KING STREET, HOLBORN.

ENGLISH EDITIONS.

THE FOUR LEADING DOCTRINES OF THE NEW CHURCH,

Signified in Revelation xxi. by the New Jerusalem; being those respecting the LORD, His Divine and Human Natures, and the Divine Trinity: the SACRED SCRIPTURE; FAITH; and LIFE. With an Introductory Preface, and an Account of the Author.

Royal 8vo., 6*s*. 6*d*.; demy, 4*s*. 6*d*.; foolscap, 3*s*.

Each of the above Doctrines may be had separate, namely,

THE DOCTRINE of THE NEW JERUSALEM RESPECTING THE LORD;

To which is added, Nine Questions on the Trinity, with their Answers.

Royal 8vo., 2*s*.; demy, 1*s*. 6*d*.

THE DOCTRINE of THE NEW JERUSALEM RESPECTING THE SACRED SCRIPTURE.

Royal 8vo., 2*s*.; demy, 1*s*.

THE DOCTRINE of THE NEW JERUSALEM RESPECTING FAITH.

Demy 8vo., 6*d*.

THE DOCTRINE OF LIFE FOR THE NEW JERUSALEM,

FROM THE COMMANDMENTS OF THE DECALOGUE.

Royal 8vo., 1*s*. 6*d*.; demy, 1*s*.

ON THE NEW JERUSALEM AND ITS HEAVENLY DOCTRINE,

As revealed from Heaven; to which are prefixed some Observations concerning the New Heaven and the New Earth.

Demy 8vo., 1*s*. 8*d*.

THE SAME WORK, without the Extracts from the Arcana Cœlestia.

Royal 8vo., 1*s*. 6*d*.

A BRIEF EXPOSITION OF THE DOCTRINE OF THE NEW CHURCH,

Which is meant by the New Jerusalem in the Apocalypse.

Royal 8vo., 1*s*. 6*d*.; demy, 1*s*.

THE TRUE CHRISTIAN RELIGION;

OR,

THE UNIVERSAL THEOLOGY of THE NEW CHURCH,

Foretold by the Lord in Daniel vii. 13, 14; and in the Apocalypse, xxi., 1, 2.

Demy 8vo., 8*s*.

THE CORONIS OR APPENDIX TO THE TRUE CHRISTIAN RELIGION.

Treating of the four Churches on this Earth since the Creation of the World; with a brief Continuation.
Demy 8vo., 1*s.*

INDEX OF SUBJECTS and PASSAGES OF SCRIPTURE

IN THE TRUE CHRISTIAN RELIGION,

Demy 8vo., 6*d.*

ARCANA CŒLESTIA:

THE HEAVENLY ARCANA which are contained in the Holy Scriptures, or Word of the Lord, unfolded; beginning with the Book of Genesis: together with Wonderful Things seen in the World of Spirits and in the Heaven of Angels. With INDEX.
Thirteen vols., demy 8vo., £3 18*s.*

The Index, or any other volume, separate, 6*s.*

INDEX TO THE ARCANA CŒLESTIA,

IN TWO PARTS,

1. Of Words, Names, and Subjects.
2. Of Passages of Scripture.

Demy 8vo., 6*s.*

(This is the Index alluded to above.)

THE APOCALYPSE REVEALED;

In which are disclosed the Arcana therein foretold, and which have hitherto remained concealed. With INDEX.

Two vols., royal 8vo., £1 1*s.*; demy, 12*s.*

INDEX TO THE APOCALYPSE REVEALED,

IN THREE PARTS.

1. Of Words, Names, and Things.
2. Of Memorable Relations.
3. Of Passages of Scripture.

Demy 8vo., 2*s.*

(This is the Index alluded to above.)

THE APOCALYPSE EXPLAINED

ACCORDING TO THE SPIRITUAL SENSE,

In which are revealed [more fully than in the preceding Work] the Arcana which are there predicted, and have been hitherto deeply concealed. With INDEX.
Six vols., demy 8vo., £1 16*s.*

Any volume separate, 6*s.*

INDEX TO THE APOCALYPSE EXPLAINED,

Demy 8vo., 3*s.*

(This is the Index alluded to above.)

A SUMMARY EXPOSITION OF THE INTERNAL SENSE

OF THE PROPHETIC BOOKS OF THE OLD TESTAMENT and of the PSALMS of DAVID. With a twofold INDEX.

Demy 8vo., 1*s.* 6*d.*

ON THE WHITE HORSE,

Mentioned in the Apocalypse, chap. xix., with References from the Arcana Cœlestia on the subject of the Word, and its Spiritual or Internal Sense. With an APPENDIX. Demy 8vo., 6*d.*

ON THE DIVINE LOVE AND THE DIVINE WISDOM.

(*Extracted from the Apocalypse Explained.*)

Demy 8vo., 1*s.*

ANGELIC WISDOM CONCERNING THE DIVINE LOVE AND THE DIVINE WISDOM.

Royal 8vo., 4*s.* 6*d.*; demy, 2*s.* 6*d.*; sewed, 2*s.*

ANGELIC WISDOM CONCERNING THE DIVINE PROVIDENCE.

Royal 8vo., 6*s.*; demy, 4*s.*

THE DELIGHTS OF WISDOM CONCERNING CONJUGIAL LOVE:

AFTER WHICH FOLLOW,

THE PLEASURES OF INSANITY CONCERNING SCORTATORY LOVE.
Demy 8vo., 5*s.*

THE INTERCOURSE BETWEEN THE SOUL AND THE BODY,

Which is supposed to take place either by Physical Influx, or by Spiritual Influx, or by Pre-established Harmony.
Demy 8vo., 6*d.*; foolscap, 4*d.*

CONCERNING HEAVEN AND ITS WONDERS, and CONCERNING HELL,

Being a Relation of Things heard and seen.
Royal 8vo., 8*s.*; demy, 4*s.*

ON THE EARTHS IN OUR SOLAR SYSTEM,

Which are called Planets; and on the EARTHS in the STARRY HEAVENS: with an Account of their Inhabitants, and also of the Spirits and Angels there; from what has been heard and seen.
Demy 8vo., 1*s.*

AN ACCOUNT of the LAST JUDGMENT

AND THE

DESTRUCTION OF BABYLON;

Shewing that all the Predictions in the Apocalypse are at this day fulfilled: being a Relation of Things heard and seen. To which is added,

A CONTINUATION CONCERNING the LAST JUDGMENT and the SPIRITUAL WORLD.
Demy 8vo., 1*s.*

FRENCH EDITIONS,

Of M. le Boys des Guays.

ARCANES CELESTES

De l'Ecriture Sainte ou Parole du Seigneur dévoilés, ainsi que les merveilles qui ont été vues dans le monde des esprits et dans le ciel des anges.

Tomes I. and II., 8*s*. each.

L'APOCALYPSE DANS SON SENS SPIRITUEL,

D'après l'Apocalypse Révélée et l'Apocalypse Expliquée 8*s*.

DOCTRINE DE LA NOUVELLE JERUSALEM SUR LE SEIGNEUR.

2*s*.

DOCTRINE DE LA NOUVELLE JERUSALEM SUR L'ECRITURE SAINTE.

3*s*.

DOCTRINE DE VIE POUR LA NOUVELLE JERUSALEM,

D'après les Préceptes du Décalogue. 2*s*.

DU DIVIN AMOUR ET DE LA DIVINE SAGESSE,

(Ouvrage Posthume.) 3*s*.

DU CHEVAL BLANC,

Dont il est parlé dans l'Apocalypse, chap. xix. 8*d*.

WELCH EDITION.

TRAETHAWD YNGHYLCH CAERSALEM NEWYDD, A'I HATHRAWIAETH NEFAWL,

Fel y datguddiwyd hi o'r Nef: ynghyd a rhai sylwiadau ynghylch y Nef Newydd ar Ddaear Newydd. Demy 8vo., 1*s*.

The above Works are translations from the Latin, except the Indexes to the Apocalypse Explained and True Christian Religion; and the French work on the Apocalypse.

LATIN EDITIONS, in 4to.

APOCALYPSIS EXPLICATA SECUNDUM SENSUM SPIRITUALEM;

Ubi revelantur Arcana, quæ ibi prædicta, et hactenus ignota fuerunt. Opus um posthum. Vols. 3 and 4, each 10*s*.

APOCALYPSIS REVELATA

In quâ deteguntur arcana quæ ibi prædicta sunt, et hactenus recondita latuerunt. 10*s*.

INDEX RERUM IN APOCALYPSI REVELATA.

Opus um posthum. 3*s*.

INDEX VERBORUM, NOMINUM ET RERUM IN ARCANIS CŒLESTIBUS.

Opus um posthum. 8*s*.

DE NOVA HIEROSOLYMA

Et ejus Doctrinâ Cœlesti: ex auditis e Cœlo. Quibus præmittitur aliquid de novo Cœlo et Novâ Terrâ. 4*s*.

DE ULTIMO JUDICIO, ET DE BABYLONIA DESTRUCTA:

Ita quod omnia, quæ in Apocalypsi prædicta sunt, hodie impleta sint. Ex Auditis et Visis. 2*s*.

QUÆSTIONES NOVEM DE TRINITATE, &c.

Ad Emanuelem Swedenborg propositæ a Thoma Hartley; tum illius Responsa. 6*d*.

SWEDENBORG'S THEOLOGICAL WORKS.

LATIN EDITIONS, in 8vo.

DOCTRINA NOVÆ HIEROSOLYMÆ DE DOMINO.

2*s.*

DOCTRINA NOVÆ HIEROSOLYMÆ DE SCRIPTURA SACRA.

2*s.*

DOCTRINA VITÆ PRO NOVA HIEROSOLYMA

Ex Præceptis Decalogi: et DOCTRINA NOVÆ HIEROSOLYMÆ DE FIDE. 2*s.*

DE DOMINO ET DE ATHANASII SYMBOLO.

Opus Posthumum. 1*s.*

DOCTRINA NOVÆ HIEROSOLYMÆ DE CHARITATE.

Opus Posthumum. 1*s.*

CANONES, SEU INTEGRA THEOLOGIA, NOVÆ ECCLESIÆ.

De Deo Uno et Infinito. De Domino Redemptore: et de Redemptione. De Spiritu Sancto. De Divinâ Trinitate. Opus Posthumum. 1*s.*

Dr. Tafel's Editions.

ARCANA CŒLESTIA

Quæ in Scriptura Sacra seu Verbo Domini sunt, detecta: una cum Mirabilibus quæ visa sunt in mundo spirituum et in cœlo angelorum.

13 vols., 10*s.* each.

THE SAME WORK, on inferior paper, each vol. 8*s.*

SAPIENTIA ANGELICA DE DIVINO AMORE ET DE DIVINA SAPIENTIA.

4*s.*

DE COMMERCIO ANIMÆ ET CORPORIS,

Quod creditur fieri vel per influxum physicum, vel per influxum spiritualem, vel per harmoniam præstabilitam. 1*s.*

DIARIUM SPIRITUALE.

E Chirographo in Bibliothecâ Regiæ Academiæ Holmiensis asservato.

Pars I. Vol. I. 12*s.* Pars IV. 4*s.*
——— Vol. II. 18*s.* —— V. 4*s.*
Pars II. ——— 11*s.* —— VI., continens Indicem
Pars III. Vol. I. & II. £1. Partium II.—IV. 4*s.*

ADVERSARIA IN LIBROS VETERIS TESTAMENTI.

Ex operibus posthumis in Bibliothecâ Regiæ Academiæ Holmiensis asservatis. Fasc. 1, 2, 3, 4. 2*s.* 6*d.* each.

DICTA PROBANTIA

Veteris et Novi Testamenti collecta et breviter explicata. E Chirographo in Bibliothecâ Regiæ Academiæ Holmiensis asservato. 4*s.*

Reports of the Society's proceedings may be had gratis *of the Publisher, W. Newbery,*
6, *King Street, Holborn.*

WALTON AND MITCHELL, PRINTERS, WARDOUR STREET, LONDON.